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THE DISTANCE GRADIENT IN VISUAL AND KINESTHETIC FIGURAL AFTER-EFFECTS

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Alexander William Pressey

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a dissertation entitled "The Distance Gradient in Visual and Kinesthetic Figural After-Effects", submitted by Alexander William Pressey in partial fulfilment of the requirements for the degree of Doctor of Philosophy

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ABSTRACT

This study was concerned with the combined effects of inspection-(I-) time and inter-figural (I-T) distance on visual and kinesthetic figural after-effects (FAEs).

A visual FAE, obtained by the method of adjustment, was defined by the degree to which a vertical line of light (T-line) was subjectively displaced following constant fixation of another line of light (I-line). The I-line was located at distances of .000, .031, .063, .125, .187, .250, and .375 inch to S's left of the T-line. I-times of 10, 30, and 50 seconds were used. One-half of the Ss made adjustments from the left, and the remainder from the right, of the T-line. A split-plot analysis of variance design was employed in which different Ss were assigned at random to combinations of I-T distance and direction of adjustment. All Ss were tested under the three levels of I-time. The order of presenting I-times was counter-balanced within each of the main conditions. 168 students were tested. An equal number of men and women were assigned to each of the conditions. The results showed that 72% of the Ss exhibited displacement in the predicted direction. A large sex difference was found; visual FAEs developed at a slower rate and reached a lower asymptote in women than in men. A distance gradient was present in male Ss only. As I-T distance increased, the magnitude of displacement increased at first and then decreased. In addition, the distance at which maximum displacement occurred increased with

I-time. This tendency resulted in different relationships between I-time and FAE. At short distances increases in I-time yielded decreases in displacement whereas, at greater distances, there was a positive relationship between I-time and displacement.

Measures of a kinesthetic FAE were obtained by determining the degree to which a 2-inch width appeared to shrink following inspection of 2.0-, 2.5-, 3.0-, 3.5-, 4.0-, and 4.5-inch widths. I-times of 10 and 50 seconds were used. A control group which rested during the I-interval was also employed. Measures were obtained from 156 Ss who participated in the visual FAE test. An equal number of men and women were assigned to each condition. The results indicated that the classical non-monotonic relationship between I-T distance and size of FAE was not present. Instead, FAE increased as a negatively accelerated function of I-width. Increases in I-time produced an increase only in the asymptotic level of the FAE. There was no difference in the performance of men and women.

It was concluded that the different relationships found in vision and kinesthesis are best explained by adopting a two-factor theory of FAEs.

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INTRODUCTION

It has been known for a long time that the appearance of an object can be altered by placing that object in a different context. The moon appears large when it is located near the horizon but seems to decrease in size at the zenith. Ever since the existence of such illusions was demonstrated, the belief has been that our understanding of perceptual processes will be enhanced if adequate explanations of illusions are developed.

At the turn of the twentieth century, psychologists began an intensive investigation of optical illusions. A large number of geometrical designs which illustrated perceptual distortions were constructed and attempts were made to provide objective measurements of these distortions. But this spate of research failed to produce the anticipated progress in understanding perception because it seemed that once the illusions were demonstrated and measured little more remained to be done.

In 1933, Gibson showed that the perception of an object could be distorted by changing the type of stimulation that was presented prior to the object. This discovery created new interest in illusory phenomena because it afforded a situation in which temporal relationships between stimulus patterns could be investigated. Eventually, Gibson's discovery led to a theory of perception by Köhler & Wallach (1944) which has been acclaimed as one of "the most original and systematic

theories that scientific ingenuity has produced" (Lashley, Chow & Semmes, 1951).

Demonstrations of Figural After-Effects

The term figural after-effects (FAEs) refers to changes that occur in the perception of a figure or object as the result of prior inspection of another figure. The general procedure for obtaining a FAE is to fixate an inspection- (I-) figure for a prolonged interval, replace the I-figure with a test- (T-) figure located near the position of the I-figure, and observe changes that occur in the T-figure. When a FAE is induced in vision, the T-figure may appear desaturated, further back in three-dimensional space, altered in size, or displaced from the position occupied by the I-figure.

The first observation of a FAE in vision was made incidentally by Verhoeff (1925). He reported that if an obtuse angle is fixated and then replaced by a straight line, the line will appear bent in the opposite direction. However, it was Gibson (1933) who provided an extensive account of FAEs and is credited with their discovery. In his first experiment a subject (S) wore spectacles which curved the visual field, convex to the left. After four days there was a marked decrease in the curvature of the field and, after removal of the spectacles, the field appeared curved in the opposite direction. The reduction of curvature was called "adaptation" and the subsequent distortion in the opposite direction

was termed "after-effect." The wearing of prisms was eliminated as a necessary condition for producing adaptation and after-effect. When Ss inspected a curved line for ten minutes, a decrease in curvature occurred and a straight line appeared curved in the opposite direction. Gibson also confirmed Verhoeff's finding that inspection of an obtuse angle results in an apparent curving of a straight line.

Gibson (1934) and Gibson & Radner (1937) reasoned that since a figure has two characteristics (shape and orientation) and since shape exhibits adaptation and after-effect, it follows that orientation should change after prolonged inspection. Using straight lines that were tilted slightly from the objective vertical or horizontal, they found that prolonged inspection reduced the apparent tilt. Furthermore, if a vertical or horizontal line was then inspected, it appeared tilted in a direction opposite to the inspected tilt.

In 1944, Köhler & Wallach broadened the scope of FAEs to include changes in size, location, and saturation of T-figures. They designed over fifty patterns which exemplified FAEs. An illustration of the kinds of phenomena which Köhler & Wallach subsumed under FAEs is shown in Figure 1A. The I-figure consists of a single black outline circle on a white ground. The fixation-(F-) point is a cross located below the circle. The T-figure consists of a F-cross and two objectively equal squares located symmetrically above and below it. The T-figure is constructed so

that, when S looks at the F-point, the upper square falls within the area previously occupied by the circle. To obtain a FAE, S first stares at the F-point of the I-figure for approximately one minute and then looks at the F-point of the T-figure. The upper square of the T-figure now appears smaller and more pale than the lower square; it also lies farther back in space.

A striking demonstration of displacement of an object in phenomenal space is provided in Figure 1B. After staring at the F-point of the I-figure which contains three outline squares, the two dots on the left of the T-figure appear much farther apart than the two dots on the right.

Figural displacement is not restricted to the plane which is parallel to the face of the S. Köhler & Emery (1947) showed that displacement also occurs in the third dimension. One of the patterns that they used is illustrated in Figure 1C. After prolonged inspection of the I-square, either T_1 and T_2 or T_3 and T_4 are shown. T_1 appears to lie in front of T_2 and T_3 lies farther back than T_4.

FAEs occur not only in vision but also in other modalities. One of the earliest demonstrations of a tactual-kinesthetic FAE was made by Gibson (1933). A convexly curved edge, cut out of heavy cardboard, was presented to blindfolded Ss who rubbed the edge for three minutes. A straight edge was then presented and all Ss reported that the edge appeared concave.

Köhler & Dinnerstein (1947) reasoned that since changes in size occurred in vision such changes should also occur in touch

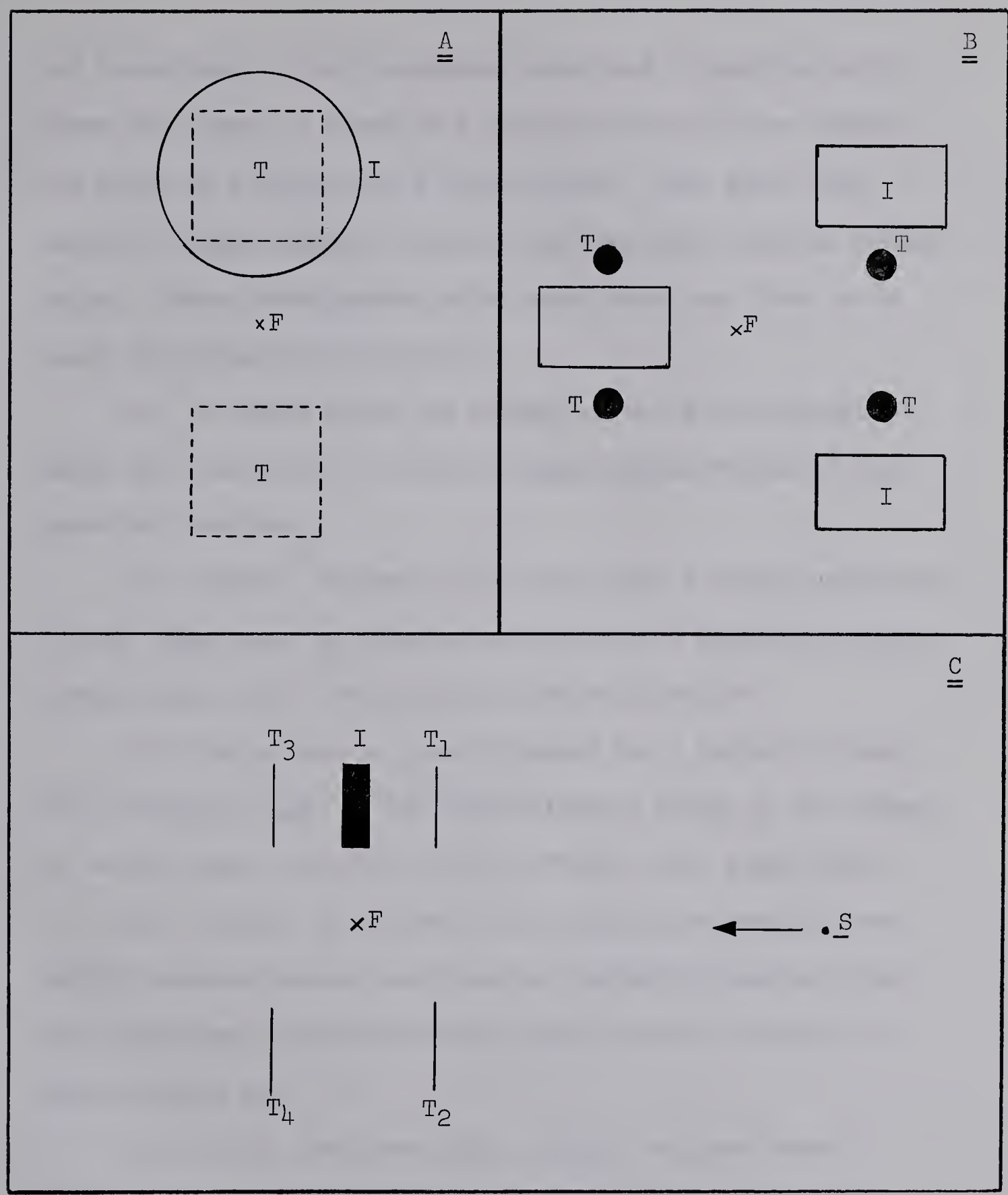

Figure 1. Inspection (I) and test (T) patterns used for inducing figural after-effects. A: Köhler & Wallach's Figure 5. B: Modified Köhler & Wallach's Figure 41. C: Köhler & Emery's (1947) pattern for inducing a three-dimensional figural after-effect.

and kinesthesis. Their procedure consisted of rubbing, with thumb and finger, a block of a certain width and then judging the width of a smaller or a larger block. They found that narrow T-blocks appeared narrower and that wide T-blocks seemed wider. These investigators also established that FAEs occur under the following conditions:

(a) If angled edges are rubbed and tests on parallel edges are then made, the parallel edges appear angled in the opposite direction.

(b) Repeated movements of a hand along a single, moderately tilted, edge cause an after-effect in which a vertical or horizontal edge seems tilted in the opposite direction.

(c) When an arm is raised forward for a period of time, two horizontal edges of the same objective height do not appear to be the same; the height on the affected side seems lower.

(d) Finally, if an area of the skin is rubbed with two widely separated edges, and then two narrowly separated edges are introduced, the latter edges appear closer together than they actually are.

It has been shown that FAEs, similar to those found in vision, touch and kinesthesis, occur in audition. Flugel's (1920) experiment on sound localization can be considered as the first demonstration of an auditory FAE. When one ear was stimulated for a prolonged time and a tone was then introduced simultaneously to both ears, the apparent source of the tone shifted towards the side which was previously unstimulated.

Deutsch (1951) attempted to establish the existence of an after-effect in pitch. He contended that a prolonged tone should increase the phenomenal interval between two neighboring tones. Computation of limens before and after contralateral monaural stimulation confirmed his prediction.

The presence of an after-effect of pitch was verified by Christman (1954) with a different technique. He reasoned that a FAE would manifest itself in a shift of a T-tone in a direction away from the pitch of a stimulating tone. His S reported that a tone of 800 cps. caused a tone of 600 cps. to be equivalent to one of 584 cps., while inspection of a 500 cps. tone caused one of 600 cps. to be equivalent to about 604 cps.

Parameters of Figural After-Effects

Quantitative studies designed to determine the effects of different stimulus conditions on the FAE were carried out concurrently with the early qualitative observations. Many of the important variables were isolated and systematically studied by Gibson (1933, 1934) and by Köhler & Wallach (1944). They observed that the most striking changes in the magnitude of the FAE occurred when variations were made in the length of time the I-figure was inspected (I-time), in the length of time between inspection of the I-figure and the T-figure (T-time), and in the distance between the I- and T-figures (I-T distance). In addition, it was noted that the structure of the sensory system and characteristics of

the S contributed to the size of the FAE. Recent studies have sought to establish the functional relationships between stimulating conditions and the FAE under more controlled conditions. A review of these experiments is presented in this section.

Inspection-time--In their preliminary explorations of visual FAEs, Gibson (1933) and Köhler & Wallach (1944) used I-times of several minutes in duration. It soon became evident that such long intervals were unnecessary. Gibson & Radner (1937) systematically studied the changes in the after-effect of tilt following I-times of 1, 5, 10, 20, 45, 90, and 120 seconds. Their results showed that the FAE increased as a negatively accelerated function of I-time and that an asymptote was reached after 45 seconds of inspection.

Hammer (1949) confirmed Gibson & Radner's results with a different configuration and procedure. Her Ss vertically aligned two short T-lines. Prior to such adjustments, I-lines located either to the left or right of a stationary T-line were presented. The measure of a FAE was the deviation of a T-setting from the point of subjective alignment (PSE) established before inspection. I-periods of 5, 10, 20, 40, 80, and 160 seconds were employed. The results showed a rapid increase in the magnitude of the FAE as I-time increased; the maximum effect occurred after 40 seconds of inspection.

Parametric studies performed in Japan (reviewed by Sagara & Oyama, 1957) revealed that the effect of increasing I-time on the

FAE was not as simple as originally assumed. Oyama (1953) used the method of constant stimuli to measure the FAE under various I-times. He found that the maximum FAE occurred as early as one second after inspection. To explain the difference between his results and those of previous investigations, he postulated that changes in I-time affect only the rate at which a FAE dissipates. That is, with short I-periods the FAE dissipates rapidly but the rate of dissipation decreases as I-time is increased. Oyama argued that the reason previous investigators found a negatively accelerated increasing relationship between I-time and FAE was that the method of adjustment was used. This method introduced a lapse of several seconds between the removal of the I-figure and the final judgment with the result that the FAE was measured after it had partially dissipated.

Oyama's explanation is plausible but two sets of results are inconsistent with it. First, a total of six experiments concerned with the effect of I-time on the FAE were carried out by different investigators in Japan. The method of constant stimuli was employed in every experiment. In three of these experiments the FAE failed to increase as I-times increased beyond one second but in the remaining three studies the FAE did increase when I-time was lengthened. Second, Duncan (1962) and Kelm (1962) failed to find a larger FAE associated with longer I-periods despite the fact that the method of adjustment was employed. Duncan's I-times were 15 and 60 seconds and he used

distance between contours as his dependent variable. There was no significant difference between the two I-times; in fact, the short interval produced a larger FAE. Kelm's method was similar to the one used by Hammer (1949). He determined the effects of 10, 30, 60, and 120 seconds of inspection on the FAE in normal and schizophrenic Ss. Statistical analysis was not performed on the data but there appeared to be a little change in the FAE as I-time increased. The results from the normal group were similar those found in Duncan's experiment inasmuch as the FAE decreased with I-times longer than 10 seconds.

Whereas the experiments dealing with the effects of varying I-time on the visual FAE have yielded contradictory results, data obtained from the kinesthetic modality have been more consistent. Four experiments in which I-time was systematically varied have been reported. In three of these experiments the procedures and response measures were similar. Kinesthetic judgments of width were taken before and after prolonged inspection of a larger or smaller I-width.

Bourne & Beier (1961) measured the amount of expansion that occurred in a 2-inch block of wood following 30, 60, 90, and 120 seconds of rubbing a 1.5-inch block. Increases in I-time failed to produce a differential effect on the FAE since the maximum amount of distortion occurred at the 30-second I-period.

Carlson (1963) measured the degree to which a 1-inch block appeared to shrink after inspection of a 2-inch block for 1, 3,

and 5 minutes. She found a significant increase in the magnitude of the FAE as I-time increased.

The effect of much shorter periods of inspection was investigated by Bakan, Myers & Schoonard (1962). They utilized an I-block of 0.5 inch, a T-block of 1.5 inches, and I-times of 10, 30, and 60 seconds. Their results indicated that overestimation of the T-block increased linearly with increases in I-time.

The most extensive sample of I-times was employed in a recent study by Singer & Day (1965). Their dependent variable was kinesthetic judgment of the horizontal position. Tests were conducted before and after controlled rythmic stimulation of the extended arm across a slanted bar. This task produced a phenomenon analagous to Gibson's after-effect of tilt in vision. The I-times were 15, 30, 45, 60, 75, 90, 105, and 120 seconds. The FAE was found to increase steadily as I-time increased and then reach a plateau after approximately 60 seconds.

All of the above studies are in substantial agreement that the kinesthetic FAE increases as a negatively accelerated function of I-time and that at least 30 seconds of inspection is required before an asymptote is reached. It should be noted, however, that an adjustment technique was used in every experiment. In light of Oyama's (1953) contention that an increasing relationship is an artifact of the adjustment method, it would be informative to determine whether a similar relationship obtains when the method of constant stimuli is employed.

Test-time.--Next to I-time, the variable of time after inspection has been investigated most extensively. Experiments concerned with measuring dissipation of the FAE have used a wide variety of configurations and procedures. The consensus seems to be that, both in vision and kinesthesis, the FAE dissipates rapidly after the removal of the I-figure and disappears almost entirely after one or two minutes of rest. Persistence beyond a few minutes seems to be the exception rather than the rule.

In 1934, Vernon studied changes in visual perception of the vertical position following 10 minutes of inspecting a line inclined at an angle of 10 degrees from the true vertical. After inspection, Ss made several adjustments of a pointer to the subjective vertical every 30 seconds. The FAE decreased gradually with time but was still noticeable 5 minutes after inspection.

Bales & Follansbee (1935) used a curved line to induce a FAE. Ss inspected the figure for a period of 5 minutes and measurements were taken immediately, 30 and 60 seconds after inspection. The FAE decreased with T-time but a residual effect was still observable at the 60-second T-period.

A well controlled experiment which sought to describe the decay of the visual FAE was conducted by Hammer (1949). Her method has been described above. A single 60-second presentation of the I-figure was followed by tests taken successively 0, 15, 50, 60, 90, 120, 150, and 180 seconds after inspection. Magnitude

of figural displacement decreased gradually as T-time increased. No effect was observable after 90 seconds of rest. A second experiment, in which only one measure at each T-period was taken, yielded substantially the same relationship.

Oyama's (1953) view that the rate of dissipation is dependent upon the length of the I-period resulted in one of the few experiments in which rate of decay was studied as a function of I-time. Ikeda & Obonai (1953) measured the FAE at various intervals ranging from 1 to 240 seconds after inspection. I-time was also varied from 1 to 240 seconds. The family of curves that resulted clearly showed that increasing I-time slowed the rate of dissipation. A subsidiary finding of interest was that the FAE did not persist beyond 240 seconds of rest even when an I-period of 240 seconds was used. Two independent investigations have since verified the results obtained by Ikeda & Obonai. Kelm (1962) plotted the rate of dissipation of the visual FAE after 10, 30, 60, and 120 seconds of inspection. In both normal and schizophrenic groups there was an inverse relationship between I-time and rate of dissipation. Duncan (1962) took 16 successive measurements of a visual FAE following 15- and 60-second periods of inspection. The 15-second group showed some dissipation but the 60-second group did not. This interaction between I-time and T-time is congruent with the view that prolonging inspection delays the rate at which the FAE decays. However, Duncan's results are surprising in one respect. This is the first experiment in

which a visual FAE failed to exhibit any decrease whatsoever as time after inspection increased.

Results similar to Duncan's were obtained by Pick, Hetherington & Belknapp (1962). Their experiment compared dissipation of Gibson's curved line effect with Köhler & Wallach's size effect following 5 minutes of inspection. Three different conditions were employed in the interval between inspection and test. In one, normal viewing of the surroundings was allowed; in another, Ss were blindfolded immediately after inspection; and in the third, goggles producing a "ganzfeld" were worn. The results indicated that the after-effect for a curved line dissipated under all three conditions but that the after-effect of size did not decrease under blindfold and ganzfeld conditions. In fact, the FAE under the ganzfeld condition increased after 30 minutes of rest.

The experiments of Duncan (1962) and Pick, et al., (1962) point out that I-time and T-time are not the only variables which affect the rate at which FAEs dissipate. And, just as the diverse effects of I-time on the development of the FAE have not been interpreted, no satisfactory explanation exists for the fact that under certain conditions the FAE fails to decline even after long rest periods. One possibility, discussed in more detail below (p. 87), is that the type of stimulus pattern affects dissipation.

Very few systematic studies have been concerned with the duration of kinesthetic FAEs. Köhler & Dinnerstein (1947) noticed that the after-effect of kinesthetic width judgments decreased slowly as time after inspection elapsed but that a

residual FAE persisted for several months after it was induced. It has since been shown that such a strong residual effect is an artifact of the method used to measure the FAE. Heinemann (1961) found that what persisted was not a FAE but a tendency to overestimate all objects. Therefore, when a FAE of overestimation is induced, as by Köhler & Dinnerstein (1947), it will be confounded by this general tendency to overestimate all objects.

Carlson (1963) described the dissipation of the after-effect of kinesthetic width judgments following 1, 3, and 5 minutes of inspection. Tests were made immediately, 1, and 7 days after inspection. The FAE decreased with rest and was not significantly present 1 day after induction. The three I-periods did not produce differential rates of dissipation.

Recently, Singer & Day (1965) measured the rate of decay of a kinesthetic after-effect of tilt. I-periods of 30 and 60 seconds were presented and measurements were made at various intervals ranging from 0 to 180 seconds after inspection. Their results showed that under both I-times the FAE had completely dissipated after 160 seconds. They concluded that the shorter I-period led to a more rapid decline in the magnitude of the FAE. However, their conclusion is unconvincing because the trends were not evaluated statistically and inspection of the slopes does not reveal a striking difference.

Distance between inspection- and test-figures.--Early in their investigation, Köhler & Wallach (1944) discovered that there was an optimum distance between I- and T-figures which

yielded a large FAE. If the T-figure was placed too close to the I-figure the resulting FAE was not striking. However, as the I-T distance was increased, the phenomenon increased in magnitude and then decreased. They called this non-monotonic relationship the "paradoxical distance effect" although they soon showed that there was nothing paradoxical about it. Quantitative estimates of the FAE were obtained from a T-figure which consisted of two squares placed horizontally in line with a F-point lying between them. The I-figure contained two solid rectangles located below and above the left and right T-squares respectively. With this configuration it is the obliquity of the T-squares which indicates a FAE. The results from 4 subjects showed that maximum displacement occurred when the distance separating the I- and T-figures was .25 inch. The viewing distance was reported to be "about three yards" which suggests that maximum displacement occurred when the I-T distance subtended a visual angle of 8 minutes.

Fox (1951) conducted two experiments in which the relationship between magnitude of visual figural displacement and I-T distance was determined. In his first study the configuration was similar to the one used by Köhler & Wallach to describe the paradoxical distance effect or "distance gradient" except that the T-figure consisted of dots instead of squares. I-T distance ranged from -0.5 to 2.0 inches, viewing distance was 80 inches, and I-time was 1.5 minutes. The method of average error was used throughout the study. The results verified the presence of a distance gradient with maximum displacement occurring between .25 and 0.50 inch.

There was, however, substantial displacement when the I- and T-figures coincided, a result which was incongruous with prevailing conceptions of FAEs. Consequently, a second experiment was conducted in which a different configuration was employed. The T-figure consisted of four dots centered symmetrically around a F-point (see Figure 1B). The two dots on the right were stationary and fixed the vertical distance at 2.5 inches. The distance between the two dots on the left could be manipulated by the S. The I-figures were rectangles which were located to the left of a F-point. These rectangles varied in width from 0.75 to 4.0 inches which provided for systematic changes in I-T distance. The procedure was the same as in the first experiment. Once again the results confirmed the existence of a distance gradient with a maximum FAE occurring at an I-T distance of approximately 0.50 inch.

Pollack (1958) described the FAE as a joint function of I-T distance and figure-ground contrast. His I-figure was a thin, black rectangle located below and to the left of a small F-point. The T-figure consisted of small squares placed symmetrically above and below a white F-point. The T-squares were white, mid-grey, and light grey. S's task was to adjust the top square until it appeared directly above the lower one. I-T distances ranged from -0.063 to 0.44 inch in steps of 0.063 inch. The distance between S and the target was one meter and I-time was 2 minutes. The data showed that a distance gradient was present for all three levels of figure-ground contrast but that the magnitude of the FAE

decreased as contrast decreased. There are two points of special interest in Pollack's results. The point of maximum displacement, which was an I-T distance of .125 inch, was the same for all levels of contrast. Second, a FAE was not present when the distance between I- and T-figures was greater than 0.31 inch. Both Köhler & Wallach and Fox reported a substantial FAE at greater I-T distances.

Kelm's (1960) method and dependent variable was very similar to Pollack's which of course was based on Hammer's (1949) work. The T-figure consisted of two vertical lines of light presented in a dark room. The bottom line was stationary and was located below and to the left of a red F-dot. The upper line was moveable in a horizontal direction by either S or the experimenter (E). The I-figure was a single vertical line placed at distances ranging from 0.0 to 1.0 inch to the left of the position occupied by the bottom T-line. I-time was 50 seconds and viewing distance was 24 inches. The data convincingly demonstrated the presence of a distance gradient. The magnitude of figural displacement increased until the I-T distance was .25 inch and then slowly decreased. A large FAE was present even at an I-T distance of 1.0 inch.

All of the above studies were concerned with vertical or horizontal displacement of a T-figure in the frontal plane. However, several Es used changes in size or depth as their dependent variables. Köhler & Emery (1947) discovered that

a distance gradient was present for FAEs in the third dimension. Their T-pattern contained two upright squares placed on either side of a F-point. The distance between S and the T-figure was 13 feet. The I-figure was a single square which was placed either to the left or right of the F-point and at various distances from the S. An I-period of 45 seconds was chosen. Every S that was tested exhibited an increase in the FAE with an increase in I-T distance. But the decrease which normally accompanies large I-T distances was not very salient. This may be due to the fact that I-T distances were not adequately sampled or it may be due to the fact that a distance gradient does not characterize FAEs in the third dimension.

Changes in the size of a figure have been studied extensively in Japan with the aim of describing the distance gradient. A change occurs in a standard circle whenever a larger circle which surrounds the standard, or a smaller circle lying within the standard, is inspected. Ikeda (1951), Ideda & Obonai (1955) and Oyama (1954) measured the amount of expansion and shrinkage of a T-circle by varying the size of the I-circle. When the FAE was plotted as a function of the ratio of I- to T-circle, it was found that a distance gradient was present both for the after-effect of shrinkage and of expansion. Moreover, it appeared that it was the relative and not the absolute distance between contours that was important. In almost all cases maximum expansion occurred when the I-circle was one-half the diameter

of the T-circle and maximum shrinkage occurred when the I-circle was twice the size of the T-circle. Another interesting fact that was discovered was that, at coincidence of I- and T-circles, there was a substantial reduction in the size of the T-circle.

All of the experiments concerned with the effect of I-T distance of the visual FAE agree that the phenomenon first increases and then decreases as I-T distance increases. Such agreement does not characterize data obtained on the distance gradient in kinesthetic FAEs.

In 1960, Krauskopf & Engen determined the amount of shrinkage that occurred in kinesthetic judgments of width following prolonged inspection of a larger width. The T-figure was a 2-inch block of wood and the I-figures were blocks ranging in width from 2.5 to 4.5 inches. Inspection consisted of rubbing one of the I-blocks with the thumb and middle finger for one minute. Tests of apparent width taken after inspection showed that the T-block became progressively narrower as the width of the I-block increased. The largest FAE was present when the I-block was 4.0 inches and the FAE decreased when the 4.5-inch block was used. Krauskopf & Engen concluded that a distance gradient does occur in kinesthetic FAEs.

An experiment by Charles & Duncan (1959) also sought to discover whether a distance gradient was present in the kinesthetic modality. They used a single I-block which was 2 inches wide and several T-blocks which varied in width from .125 to 2.0

inches. A 60-second period of inspection was presented. Their results indicated that shrinkage of the T-blocks increased at first and then decreased as the width of the T-blocks decreased (see Appendix G).

On the other hand, Costello (1963) and Nachmias (1953) failed to find I-T distance to be an effective variable for producing changes in the magnitude of a kinesthetic FAE. Costello's method was much like that used by Krauskopf & Engen. He measured the kinesthetic FAE as a joint function of I-time and I-T distance. The T-block was 1.5 inches wide and the I-blocks were 2.5, 3.5, and 4.0 inches wide. I-times of 5, 30, and 60 seconds were used. It was reported that the FAE increased as a function of I-time but that the width of the I-block was an ineffective variable. Nachmias (1953) reached a similar conclusion with a different method. The I-condition involved placing one hand in a resting position at a certain height. In the T-condition both hands were placed at the same level either above or below the I-position. The difference in the distance between I- and T-positions did not alter the size of the FAE.

Thus, the question of whether a distance gradient characterizes kinesthetic FAEs remains unresolved. The experiments reporting negative findings are inconclusive because the range of I-T distances employed was restricted. On the other hand, experiments reporting positive results are also inconclusive because of weak

procedures and interpretations of results. These considerations are dealt with in greater detail below (p. 90).

Several investigators have been concerned with the distance gradient in auditory localization. It will be recalled that a FAE of auditory localization occurs when a T-tone changes position because of prior stimulation by an I-tone in a different location. Jones & Bunting (1949) determined the location of the medial plane before and after hearing tones placed 60 and 90 degrees to one side of the medial plane. A FAE was present and was larger when the I-tone was displaced 60 than when it was displaced 90 degrees. They took this result as evidence of a distance gradient in auditory space. Three I-positions were studied by Krauskopf (1954) in an attempt to extend Jones & Bunting's data. Once again, a shift in the medial plane was reported with the amount of shift increasing with increasing I-T distances. By combining his results with those of Jones & Bunting, Krauskopf concluded that a distance gradient obtains in the after-effect of auditory localization.

A well controlled study by Taylor (1962) provided convincing verification of a distance gradient. He measured the amount of displacement of a T-tone for separations covering the range from zero to 102 degrees. He found that the magnitude of displacement increased to a maximum at 30 degrees and decreased to zero at 102 degrees. No displacement occurred at coincidence of I- and T-tones. A comparison with Krauskopf's results indicated that displacement was of the same magnitude in the two studies.

The above experiments support the view that visual and auditory FAEs increase at first, then decreases, as I-T distance increases. Kinesthesis is the only modality for which evidence of a distance gradient is inconclusive since two investigations have found a distance gradient while the remaining two have not.

Other Variables.--The effects of many other stimulus variables on FAEs have been investigated. Graham (1961) determined the effects of contrast between the I-figure and its ground. Her method of inducing and measuring the FAE was identical to Hammer's (1949) technique. To obtain changes in contrast, a series of figures varying from light grey to black were drawn on white backgrounds. After an I-period of 60 seconds, it was found that the magnitude of figural displacement increased with increasing contrast between figure and ground. These results are in line with data obtained by Nozawa (1953), Pollack (1958), and Yoshida (1953) who also showed that the visual FAE was positively related to contrast.

A variable which has been subjected to a considerable amount of experimentation is hue. Köhler & Wallach (1944) stated that they obtained FAEs when the object and its environment had the same brightness but differed in color. Hochberg & Triebel (1955) conducted a series of experiments using chromatic I-figures and chromatic and achromatic T-figures. They concluded that chromatic differences neither modified nor generated FAEs. Takagi &

Ishikawa (1956) also used chromatic I- and T-figures. They reported that I- and T-figures of the same hue yielded considerable FAEs but that there was less effect when the I- and T-figures were of different hues. Day (1959) and Crawford & Kubala (1964) equated brightness of figure and ground but changed hue. They found that hue was capable of generating FAEs independent of brightness differences, but differential FAEs did not result as a function of differential hue. The soundest conclusion that can be drawn from these experiments is that FAEs are observable whenever there are contours between figure and ground irrespective of whether these contours are due to brightness or hue differences.

In addition to hue, several other variables have been found to be ineffective in altering the FAE. A difference in the level of background illumination fails to affect the magnitude of displacement provided that contrast between the I-contour and its ground remains constant (Freeburne & Hamilton, 1949; Fujiwara & Obonai, 1953; Graham, 1961). Area of the I-figure is another ineffective variable as long as the distance between I- and T-figures does not vary (Duncan, 1962; Graham, 1961). Lastly, Duncan showed that the type of I-figure does not produce a significant change in the FAE despite Köhler & Wallach's (1944) claim that outline and solid figures produce different effects.

Two anatomical aspects of the visual system have been found to alter FAEs. The first of these is the retinal position on which I- and T-figures are projected; that is, whether the FAE is induced in the foveal or peripheral regions of the retina. The second factor relates to the problem of whether FAEs have a retinal or a cortical locus. Traditionally, a solution to this latter question has been sought by determining whether or not inter-ocular transfer of the FAE occurs.

Gibson (1933) compared foveal and peripheral stimulation by a bent line and reported that the FAE spread further in the periphery. Köhler & Wallach (1944) reported their impression that the size of the FAE was greater when it was induced in the peripheral, as opposed to the foveal, regions of the retina. A systematic investigation of the effect of retinal locus on the magnitude of the FAE was conducted recently by Meyer, Sukemune & Myers (1960). The amount of shrinkage of a small T-circle, as determined by the method of constant stimuli, was used as the dependent variable. The I- and T-circles were located 2, 4, and 6 degrees from the fovea. They found that the FAE was largest when the interacting figures were peripherally located.

Experimental attempts to determine the relative contributions of the retina and the cortex have been decidedly limited despite the fact that interest in the phenomenon of FAE has been generated and fostered by the belief that FAEs reflect basic cortical processes. The basis for the view that FAEs occur at the cortex

is the fact that there is inter-ocular transfer of the effect. Gibson (1933) compared the magnitude of the FAE when the same eye was used for inspection and test with that when alternate eyes were used. He found that in the latter case the FAE was reduced by about 40%. Incidental observations by Köhler & Wallach (1944) and Weitz & Compton (1950) confirmed the presence of a FAE when one eye was used for inspection and the other for testing. But the magnitude of the effect was greatly reduced under such conditions. The view that inter-ocular transfer provided an experimentum crucis for the contention that FAEs have a cortical locus has been challenged by Marks (1949). He pointed out that negative after-images exhibit transfer and that, therefore, inter-ocular transfer of FAEs may be simply a manifestation of this phenomenon. Obviously, additional experimental and theoretical work is needed to establish the significance of transfer and, more important, to ascertain whether the problem of locus is a fruitful or meaningful one.

A research orientation which is unconcerned with the problem of locus is that which is directed towards assessing individual and group differences on the FAE. The primary aim of such research is to correlate the FAE with stable cognitive and personality characteristics. A major avenue into this area was instigated by Klein & Krech (1952) and pursued by Wertheimer (1954), Eysenck (1955), and Spitz (1959).

Klein & Krech (1952) measured the amount of shrinkage that occurred in a 1.5-inch width following inspection of a 2.5-inch width. Normal and brain-damaged Ss were tested. They found that the brain-damaged group evidenced larger FAEs than the normal group but this difference was not statistically significant. Wertheimer, Lipton, Herring, Greenhouse & Means (1965) confirmed the presence of a larger kinesthetic FAE in brain-injured patients but, as in the study by Klein & Krech, the difference was not statistically significant ($p < .10$).

Wertheimer & Wertheimer (1954) developed a theory of FAEs based on the concept of metabolic efficiency and predicted that various physiological and behavioral indices of metabolism would correlate highly with the magnitude of FAE. These predictions were generally confirmed. Furthermore, Wertheimer (1954) showed that schizophrenics who are characterized by a decrement in metabolic efficiency also exhibit smaller FAEs. Kelm (1962) verified Wertheimer's findings and also established that lysergic acid diethylamide which produces schizophrenic-like symptoms results in a FAE pattern of response that is characteristic of schizophrenics.

In 1955, Eysenck expanded on the work of Pavlov (1941) and Köhler & Wallach (1944) and predicted that extraverts would show larger FAEs than introverts. He compared the kinesthetic FAE of extraverted and introverted individuals and found that the after-effect was greater in the former group. This result, however, was

not confirmed by subsequent investigations of Rechtschaffen (1958) and Rechtschaffen & Bookbinder (1960). Neither visual nor kinesthetic FAEs significantly differentiated between extraverts and introverts.

Comparisons of visual FAEs between normal and mentally retarded Ss of the same chronological age have been made by Spits & Blackman (1959) and Prysiazniuk & Kelm (1963). Results from these experiments agreed that retarded adults showed smaller FAEs than normal controls. In addition, Spitz & Lipman (1961) found that after-effects of kinesthetic width judgments were not as great in retardated as in normal Ss.

The study of individual and group differences on tests of FAEs is still in its infancy but it may prove to be a major progressive step in understanding normal and abnormal behavior. Furthermore, a knowledge of the effect of organismic variables on the FAE could provide a method for evaluating prevalent theories of FAEs. It is to these theories that we now turn.

Theories of Figural After-Effects

The theories that have been put forward to explain FAEs fall into two broad categories. One type may be termed "frame of reference" theory and the second type "neurophysiological" theory. Frame of reference theories consider FAEs to be percepts which develop in relation to, or deviate from, an established norm. The emphasis is placed on a norm which is either inherent or

acquired through past experience. The theories of Gibson (1933) and Helson (1964) invoke a norm to explain FAEs. Neurophysiological theories, on the other hand, explain FAEs on the basis of concepts derived from neuroanatomy and physiology. These concepts are modified and extended so as to incorporate a broad spectrum of empirical data. Köhler & Wallach (1944), Osgood & Heyer (1952) and Deutsch (1964) exemplify the neurophysiological orientation.

Frame of reference theories.--Gibson's normalization hypothesis was proposed primarily to explain FAEs which are induced by prolonged inspection of curved and tilted lines. He argued that any frequent condition of the environment tends to become a norm of the phenomenal world and new stimuli are perceived in relation to it. For example, a straight line is the neutral form of all curved lines and vertical or horizontal lines are norms from which tilted lines depart. Hence, the reason that a curved line becomes phenomenally less curved after prolonged inspection is due to the fact that it adapts to a netural state. This notion can be clarifield by an analogy from color vision. Grey is the neutral member of the color family. If a chromatic color is inspected for a prolonged time it will eventually approach a grey color. In the same manner, a curved line will approach the shape of the neutral member of the family of curves, viz., a straight line. The aftereffect of curvature is due to a shift of the norm itself. That is, after inspection of a curved line, the norm is no longer a straight line but a slightly curved one. When a straight line is viewed, it

is perceived in relation to this new norm and thus appears curved in an opposite direction.

The normalization hypothesis is confronted by two major difficulties; the first is an empirical and the second a logical one. A prediction that necessarily follows from Gibson's theory is that an I-figure which coincides with an existing norm will be ineffective in producing a FAE. For example, if a vertical line is the I-figure and a tilted line the T-figure, then no after-effect of tilt should be observed. But Köhler & Wallach (1944) employed just such a condition and found that a significant FAE did result.

The logical weakness in normalization theory is that no criterion is provided for assessing what is and what is not a norm. While it is intuitively compelling to conceive of the vertical and horizontal as being norms for spatial orientation, norms for attributes such as size and depth are not as easily specifiable. And yet it is a fact that changes in size or depth are readily observable when a FAE paradigm is employed. Gibson's normalization hypothesis must be modified and elaborated if it is to attain the status of an adequate theory of FAEs.

Helson's adaptation level theory is very similar to Gibson's point of view. The theory was not developed specifically to account for FAEs, but rather, was intended as a general theory of behavior. The basic postulate is that organisms establish subjective standards by pooling all stimuli that have confronted

it in the past and that are presently impinging upon it. These standards or adaptation levels are approximated as weighted log means of all stimuli affecting the organism. Once a certain adaptation level is attained, stimuli may act as "anchors" to shift that level; intense stimuli shift adaptation level upward and weak stimuli shift the level down. A key assumption is that all stimuli are perceived or judged in relation to the momentary adaptation level. Stimuli above adaptation level elicit "greater than" responses, stimuli near adaptation level evoke indifferent responses, and those below adaptation level elicit "smaller than" responses.

Adaptation level theory is clearly applicable to many of the phenomena subsumed under FAEs. Inspection of a figure establishes one adaptation level. When a T-figure is subsequently introduced, the level shifts in the direction of the T-figure and a second level is established. This new level is intermediate between the I- and T-figures and it is to this new level that displacements are referred. Thus, FAEs will be manifested by displacements of the T-figure away from the location of the I-figure except in the case where I- and T-figures coincide.

The greatest single weakness of adaptation level theory, as applied to FAEs, is that it fails to make explicit the manner in which stimulus variables change adaptation levels. One problem is whether an anchor (I- or T-figure) is maximally effective as soon as it is observed or whether prolonged presentation of an

anchor progressively shifts the adaptation level. Several authors (e.g., Costello, 1963; Taylor, 1962) have argued that results indicating that the FAE fails to increase as I-time increases are better explained by frame of reference than by alternative theories. On the other hand, Helson (1964) specifically states that, according to his theory, increases in I-time will result in larger FAEs. The fact that such a contradiction in interpreting frame of reference theory occurs makes it evident that considerable ambiguity exists.

Another fact which is not easily reconciled with adaptation level theory is that FAEs decrease as time between inspection and test increases. According to Helson, adaptation level is changed only by the introduction of relevant stimulation; spontaneous changes will not occur. But Pick, et al., (1962) have shown that even when the T-period is relatively unfilled, the after-effect of a curved line still decreases.

Finally, there is ample evidence to indicate that, when circumscribed figures are employed, displacement occurs even when I- and T-contours coincide. This phenomenon is at variance with adaptation level theory because coincident contours cannot change adaptation level.

There are several other facts which cannot be readily integrated into adaptation level theory but the above examples suffice to show that Helson's theory must be made more explicit if it is to become a useful theory of FAEs.

Neurophysiological theories.--Köhler & Wallach (1944) proposed a highly systematic explanation of FAEs within the framework of isomorphism and field theory. Isomorphism refers to the view that molar physiological processes parallel psychological processes. Spatial and temporal orderings of experience correspond to spatial and temporal orderings of physiological processes. Thus, if a circular shape is perceived, a circular-like process occurs somewhere in the brain, probably at the visual cortex.

Prior to developing their theory, Köhler & Wallach provided an extensive phenomenological analysis of FAEs. They classified the types of changes that were induced by prolonged inspection of objects and also tried to specify the optimum conditions under which FAEs were manifested. Their research led them to conclude that a single theoretical construct would encompass much of the empirical data if three main conditions were satisfied. First, the construct had to represent a process which developed with protracted stimulation and had the effect of obstructing further stimulation. Second, the process had to extend beyond the region of stimulation, and finally, the process had to be strongest near the boundary of an object and decrease as distance from the boundary increased.

Köhler & Wallach noted that all of the above conditions would be satisfied if the process underlying the perception of and object were an electrical current which flowed as a volume conductor. Whenever a contour was present, afferent impulses

would establish a brightness gradient or its physiological counterpart at the cortex. Brightness would be greatest at the location corresponding to the contour but would decrease with increasing distance from the contour. Under these conditions a quasi-steady current would flow. This current would flow in short loops near the boundary of an object but the loops would progressively grow as the distance from the boundary increased. Since it is known that longer loops mean higher resistance and shorter loops mean lower resistance, the intensity of the current would be greater at the boundary than outside it.

The electrical current would have an additional characteristic. As it flowed through the neural tissue, the cells would become polarized or less permeable with the result that subsequent currents would be weakened and deflected from their initial distributions. The direction of current deflection would always be away from the region of greatest polarization because a basic characteristic of electrical current is that it always flows towards the region of least resistance.

Köhler & Wallach called the decrease in permeability of cells which results from intense electrical current "electrotonus" or "satiation." Their theory of FAEs has since been termed "satiation theory."

The phenomenon of figural displacement and the effects of I-time, T-time, and I-T distance on the magnitude of the FAE are readily explained on the basis of satiation theory. If a

straight vertical line is inspected for a prolonged interval, satiation will develop at and around the contour. Intensity of satiation will be of greatest at the contour but will decrease with an increase in distance. If a T-line is introduced at a point slightly to one side of the position of the I-line, the current from the T-line will be weakened because of the high level of satiation and it will be deflected because of the gradient of satiation. The T-line will appear desaturated and located further away from the I-position than it normally would be.

The fact that the FAE increases as a negatively accelerated function of I-time is explained by the assumption that electrical current limits itself by its own action. At the beginning of inspection the current is strong and this gives rise to the rapid development of satiation. But as satiation increases the strength of the current decreases with the result that increments in satiation also decrease.

Köhler & Wallach explain the decrease in the FAE as time after inspection increases by proposing that satiation decreases with rest; that is, the affected cells recover. This recovery process is assumed to be just one of the many manifestations of biological regeneration. As satiation declines, the T-current is deflected to a lesser degree and the size of the FAE decreases.

The presence of a distance gradient is explained in the following manner. When an I-line is inspected satiation develops

symmetrically about that line. If a T-line is located exactly at the position of the I-line, it will not be displaced because satiation on one side of the T-line is exactly the same as on the other. Consistent deflection in any one direction cannot occur. If the T-line is placed at a great distance from the I-line, again it will not be displaced because the I-current barely extends into that region. Between these two positions, great distance and coincidence, the T-line will be located in a region where satiation is greater on one side than on the other. Consequently, more of the T-current will be diverted towards the less satiated side and phenomenal displacement will result. As the T-line is moved from the periphery of satiation towards the I-line, the magnitude of displacement will increase and then decrease. The reason for the decrease is that, near coincidence, satiation from the I-line extends <u>beyond</u> the location of the T-line with the result that the amount of satiation on either side of the T-line approaches equality.

It is clear from the above exposition that satiation theory is capable of explaining not only perceptual changes that accompany prolonged inspection of objects but also the effects of different stimulus variables on these changes. However, two major difficulties have plagued satiation theory ever since its inception. The first is the presence of a logical contradiction and the second is the fact that it is not possible to derive unambiguous predictions regarding the interaction of several independent

variables on the size of the FAE. To a large extent these two problems are interrelated.

The logical difficulty revolves around the question of what is the immediate effective cause of figural displacement. Is it the level of satiation or is it the gradient of satiation that is responsible for figural displacement? Throughout their exposition, Köhler & Wallach emphasize that it is not the absolute level but rather the differential level (gradient) which causes displacement. This contention is particularly clear in their account of the distance gradient. At coincidence of I- and T-lines the absolute level of satiation is very high but displacement does not occur because satiation is symmetrically distributed on both sides of the T-line. In this case displacement is clearly related to the differential, and not the absolute, level of satiation.

On the other hand, Köhler (1965) claims that satiation theory is not contradicted by the fact that phenomenal shrinkage of a T-circle is more striking than phenomenal expansion (see Sagara & Oyama, 1957). He argues that "In the neighborhood of an I-circle, satiation inside must be stronger than satiation outside. Hence, a smaller T-circle inside an I-circle will be more strongly displaced than a T-circle outside the I-circle." The contention that satiation inside a circle is greater than outside is consistent with Köhler & Wallach's main thesis. But while the level of satiation is greater, the gradient inside a circle is not as pronounced as

outside. For, if satiation overlaps and summates, the area within a circle will become relatively homogeneously satiated. In other words, asymmetry of satiation will decrease and this should result in diminished FAEs. But Köhler argues that satiation is stronger and this should lead to greater displacement. In this case, Köhler feels that the effective cause is level of satiation and not gradient--a contention that clearly contradicts his earlier proposition. There appears to be no way in which this contradiction can be resolved at the present time.

A second weakness of satiation theory lies in the fact that it does not specify how the pattern of satiation around an object changes as I-time increases. Precise specification is necessary if predictions regarding the interaction of such variables as I-time and I-T distance on the FAE are to be derived. There are two main ways in which I-time may affect the distance gradient. The optimum distance (I-T distance that yields the largest FAE) may change or the maximum size of the FAE may change. This leads to a prediction of at least four logically exclusive alternatives regarding changes that may occur in the distance gradient as I-time increases. These alternatives are schematically represented in Figure 2. Figure 2A defines the case in which increasing I-time does not produce a change in either optimum I-T distance or maximum size of the FAE. In Figure 2B, the maximum FAE remains constant but the optimum I-T distance increases with I-time. Figure 2C indicates that the maximum FAE increases as I-time is prolonged

but that optimum I-T distance remains constant. Finally, in Figure 2D both the maximum size of the FAE and the otpimum point of displacement progressively increase.

Of these four mutually exclusive alternatives, only the relationship shown in Figure 2A can be confidently rejected on the basis of Köhler & Wallach's theory. The remaining three are not inconsistent with satiation theory. Pollack (1958) contended that satiation theory predicts changes in the distance gradient that are depicted in Figure 2C. In fact, his empirical findings support the view that changes in stimulus variables do not alter the optimum I-T distance but result only in increased maximum FAEs. On the other hand, the relationships illustrated in Figures 2B and 2D are also consistent with satiation theory. According to Köhler & Wallach, prolonged inspection of an object causes satiation to develop rapidly at the boundary which in turn obstructs subsequent I-current and deflects it away from the boundary. The heavily satiated region near the boundary thus becomes <u>broader</u> with the result that a T-figure must be located farther from the I-position if it is to exhibit large displacement.

The fact that an unambiguous prediction regarding the interaction of such variables as I-time and I-T distance cannot be derived is a serious flaw in satiation theory. But this weakness can be overcome by revising the theory in strict accordance with empirical data.

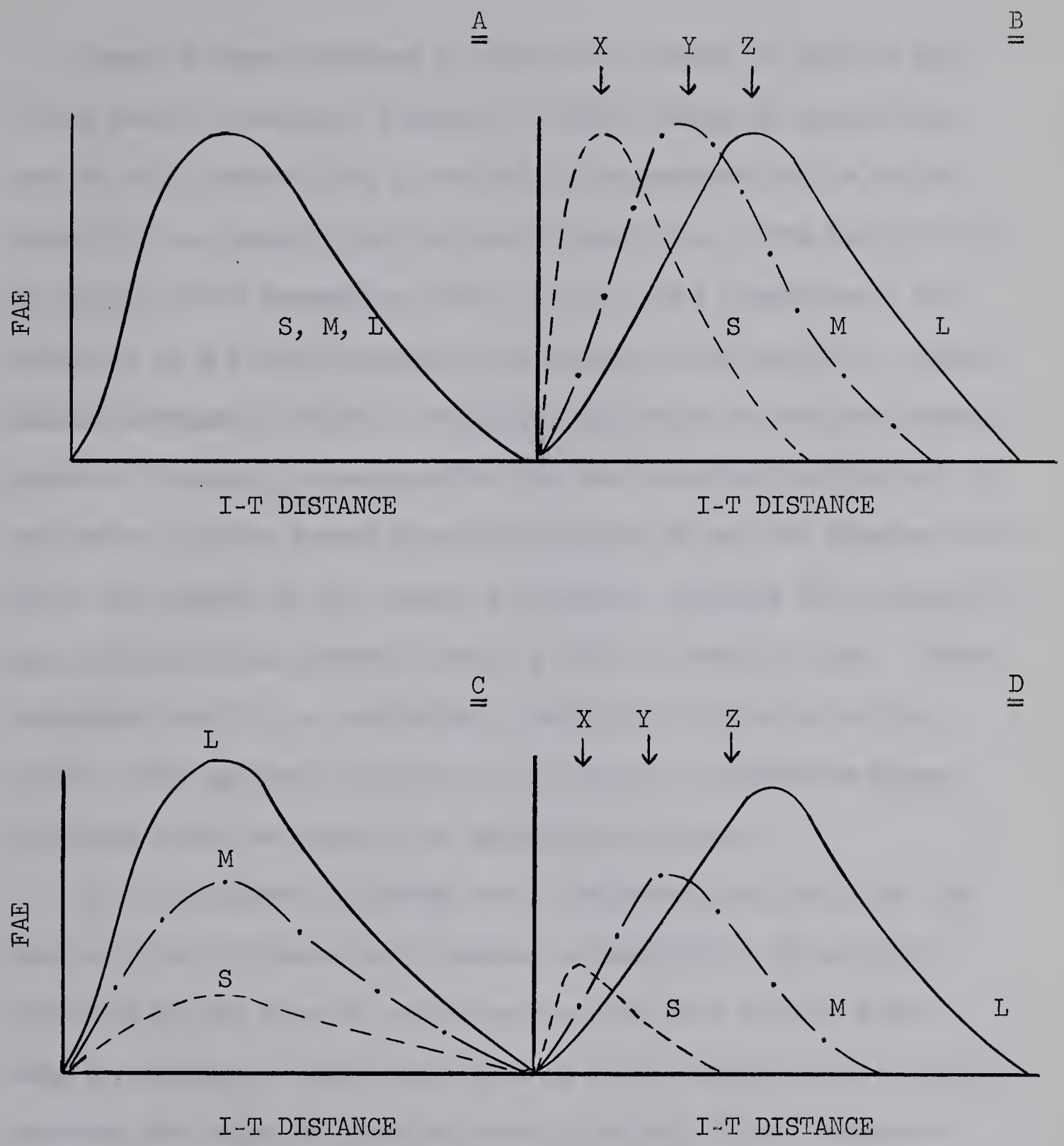

Figure 2. Hypothetical representations of the distance gradient as a function of I-time. Short (S), medium (M) and long (L) I-times are presented. X, Y, and Z define locations of T-figures.

Osgood & Heyer proposed a statistical theory of FAEs in 1952. It was based on Marshall & Talbot's (1942) theory of contour perception which states that a contour is represented at the cortex (Area 17) as a normal distribution of excitation. The distribution is assumed to be symmetrical about its own axis transversely and extending as a ridge throughout the length of the contour. Physiological nystagmus, which is the continual motion of the eye during constant fixation, is responsible for the Gaussian distribution of excitation. Every second there are between 10 and 100 tremors which cover two seconds of arc, about 5 movements covering four seconds of arc, and about one movement covering thirty seconds of arc. These movements result in a statistical peaking of excitation at the cortex. The apparent location of a contour in subjective space coincides with the location of maximum excitation.

If an I-figure is fixated for a prolonged time, cells at the cortex become differentially adapted as negatively accelerated functions of the rate of excitation and the time through which they are excited. Adaptation, in this case, refers to the commonly observed fact that the impulse rate of sensory fibers decreases under continuous stimulation and then reaches a comparatively steady state. It follows that after inspection there is a statistical distribution of <u>adaptation</u> around a contour. If a T-figure is introduced the distribution of excitation around that figure is not symmetrical. Because of differential adaptation the rate of excitation is higher in the less adapted regions. The

distribution of excitation is skewed in a direction away from the position of the I-figure and the peak of excitation shifts away from the I-figure. Since the phenomenal contour corresponds to the peak of excitation, the T-figure is subjectively displaced in space.

Statistical theory explains the apparent change in the distance of a T-figure on the basis of contour shifts and set. If an enclosed figure such as a square is viewed after prior inspection of a larger or smaller square, it changes in size because contours are displaced. But if the observer is set to make judgments of distance, the change in size is interpreted as a change in distance.

The fact that a T-figure appears desaturated is explained by the assumption that contrast is a direct correlate of differences in the amplitude of excitation in two adjacent regions. Since the edge of a T-figure falls in an area of adaptation, the amplitude of excitation is diminished and the figure appears more pale than normal.

Osgood & Heyer explain the presence of a distance gradient in exactly the same manner as Köhler & Wallach. When I-T distance is great, adaptation from the I-figure is not intense enough to affect the distribution of excitation produced by the T-figure. When I- and T-figures coincide, the pattern of excitation around the T-figure is not altered because the adaptation gradient is symmetrical. Thus, displacement does not occur at coincidence or at large I-T distances. As I-T distance increases the adaptation

gradient affects the excitation gradient to a greater and greater degree with the result that phenomenal shift of the T-figure increases. But at a certain I-T distance the adaptation gradient begins to have a smaller effect on the pattern of excitation and phenomenal displacement decreases.

There are several difficulties which are unique to Osgood & Heyer's theory and these relate primarily to the concept of physiological nystagmus. Involuntary eye tremors cause scanning of a target within a range of approximately 30 seconds of arc. Yet many investigators (e.g.,Bevan, 1951) have found FAEs to occur when the distance separating I- and T-figures is as great as 6 degrees. Obviously some process other than nystagmus must be invoked to account for the fact that adaptation occurs at such a great distance.

Krauskopf (1960) posed the question of whether nystagmus is necessary for producing FAEs. He measured a FAE with a "stopped-image" technique. With this technique the target moves in exactly the same direction as the eye with the result that fresh retinal elements are not activated as fixation is prolonged. His results showed that the FAE was just as striking under the stopped-image condition as under normal viewing conditions. Krauskopf concluded that nystagmus is not necessary for producing FAEs.

Statistical theory is subject to many of the criticisms that have been leveled at satiation theory. The main criticism is that it is not possible to derive unambiguously the changes that

will occur in figural displacement when several independent variables are allowed to interact. The variables of I-time and I-T distance may be taken once again as examples. Osgood & Heyer state that the adaptation gradient which is consequent upon prolonged inspection of a figure approximates a Gaussian distribution. But a normal statistical distribution may vary in range and also in degree of kurtosis. It is possible that prolonged inspection involves changes in either or both of these characteristics. Consequently, unless the exact changes in the statistical distribution are specified, the joint action of I-time and I-T distance on the FAE cannot be predicted.

Another neurophysiological theory of FAEs, which may be called inhibition theory, was proposed recently by Deutsch (1964). There are three basic postulates. First he assumes that an excited element inhibits other less excited elements--the degree of inhibition decreasing with distance. Second, he assumes that when an excited element ceases to be excited, its excitability will transiently diminish below its previous baseline. The elements which were previously uninhibited undergo a corresponding transient increase in excitability. Finally, Deutsch assumes that subjective distance between points is measured in the nervous system by taking an index of excitability of points lying between them. Decreasing excitability of the intervening points results in an overestimation of distance while increasing excitability leads to an underestimation of distance.

Figural displacement is explained in the following manner. When an I-line is inspected and is then replaced by two T-lines located on either side of the I-line, the subjective distance between the T-lines is greater than normal because the region between these lines is decreased in excitability. But if both T-lines are located on one side of the I-line, the subjective distance between them decreases because they lie in a region of increased excitability. Furthermore, if the pair of lines lie close to the I-line, the decrease in the distance between them is less than if the two lines were located farther from the I-line. Of course, when the distance from the I-line is very great no FAE occurs. Thus the classical distance gradient is predicted by Deutsch's theory and it is based on the assumption that the degree of inhibition falls off with distance from the excited point.

Inhibition theory does not consider what the effect of increasing I-time is on the extent of inhibition of elements which lie adjacent to the excited elements. Nor does it attempt to specify whether excitability of elements changes as time after inspection elapses. In this respect, Deutsch's theory is even less adequate than either of the two neurophysiological theories considered earlier. The criticisms of satiation theory outlined earlier are also applicable to inhibition theory.

Summary.--Both frame of reference and neurophysiological theories of FAEs are capable of explaining many of the phenomenal changes that accompany prolonged inspection of objects. Yet none of these theories is comprehensive or precise enough to account for all of the effects that are attendant upon extended fixation. The main difficulty that all theories face is that their assumptions are not stated in a clear and unambiguous manner with the result that interactions between independent variables cannot be predicted. Of the theories that have been proposed, Köhler & Wallach's satiation theory is the most adequate. It incorporates more empirical data than any other theory and, in addition, it has led to much fruitful research. It appears that satiation theory will continue to provide the main orientation for investigations of FAEs and that it will not be supplanted until alternative theories are extended to subsume existent data more adequately than satiation theory.

Statement of the Problem

A review of the experiments dealing with FAEs reveals that most investigators adopted a univariate as opposed to a multivariate approach. That is, FAEs were measured as a function of a single variable rather than as a simultaneous function of two or more variables. A weakness of the single variable approach is that different investigators studying the same variable may obtain contradictory results if the levels of additional variables

are very different. This problem is illustrated in the area of FAEs where no agreement exists on the effect of increasing I-time on the magnitude of figural displacement. Gibson & Radner (1937), Hammer (1949) and Nozawa (1953) reported that visual figural displacement increased as a negatively accelerated function of I-time; an asymptote was reached only after approximately 50 seconds of inspection. On the other hand, Duncan (1962) and Kelm (1962) found that I-times greater than 10 or 15 seconds did not enhance the FAE. Finally, many of the experiments carried out in Japan (Sagara & Oyama, 1957) showed that the maximum FAE was present after 1 second of inspection. Although all of the above investigators sampled the same range of I-times, the distance between I- and T-figures varied across experiments. And it is this variation in I-T distance which may be responsible for the diverse findings.

The proposition that increases of I-time can result in very different functions at different I-T distances is clarified in Figures 2B and 2D. It will be recalled that these Figures illustrate the hypothesis that the distance gradient changes in two ways with increasing I-time. First, the maximum distance at which a T-figure is affected increases, and second, the I-T distance at which optimum displacement occurs also increases. If a T-figure is located at X and I-time is varied, displacements will <u>decrease</u> with an increase in I-time. If the T-figure is located at Y, displacement will increase at first and then

decrease. Finally, displacement will increase as a negatively accelerated function of I-time if the T-figure is placed at Z. It is obvious from this analysis that, if the distance gradient changes with I-time and if I-T distance is not controlled, the obtained relationships between I-time and FAE will vary greatly. The first aim of the present study was to determine whether the distance gradient of the visual FAE varies as a function of the length of time that an I-figure is inspected.

A second objective was to describe the distance gradient as a function of I-time in kinesthesis. Use of a second modality was prompted by the theoretical problem of whether FAEs from different modalities are the result of the same psychological or physiological process. Charles & Duncan (1959), Köhler & Dinnerstein (1947) and Krauskopf & Engen (1960) argued that separate explanatory concepts are not necessary since variables such as I-time, T-time, and I-T distance have similar effects on kinesthetic and visual FAEs. But the empirical evidence on I-T distance is not conclusive. Charles & Duncan and Krauskopf & Engen reported that the classical non-monotonic relationship between I-T distance and FAE found in vision was also present in kinesthetic judgments of width. Costello (1963) and Nachmias (1953), on the other hand, failed to find a distance gradient and this can be construed as evidence against the proposition that FAEs from different modalities are the result of a single process.

The present study sought to provide a sensitive test of the view that kinesthetic and visual FAEs are due to the same process by comparing the effects of interacting variables on both kinds of FAEs. It was reasoned that if I-time had the same effect on the distance gradient in both modalities, then a single factor would suffice to explain all FAEs. On the other hand, if the effect of I-time on the distance gradient was different for the two modalities, this would be evidence against a "one-factor" interpretation.

In summary, the purpose of the present study was to ascertain the effect of increasing I-time on the distance gradient in visual and kinesthetic FAEs.

METHOD

Apparatus

The apparatus used for measuring visual figural displacement was similar to those used by Hammer (1949) and Kelm (1960). It consisted of a wooden base which was 22 inches long, 10 inches wide, and 7 inches high. The base was oriented so that the narrow end faced the S. A 4- x 10- x .5-inch groove was cut out at the top-front of the base and lined with rigid plastic. A 4- x 9- x .5-inch plate, also lined with plastic, was inserted into the groove. The plate was carefully machined so that it moved freely in a horizontal direction but had negligible slop movement. A metal stop was secured to the base on the right side of the apparatus. This stop defined the "standard position" of the moveable plate. A spring was attached from the stop to the plate and this allowed the plate to be displaced to S's left and then rapidly returned to the standard position.

A 7- x 6- x 6.5-inch metal frame was secured to the base just at the rear of the moveable plate. This frame housed a gear assembly which moved a panel at the front of the frame. A 20-inch metal rod linked the gear assembly to a knob which was located at the right-front of the entire apparatus. Movement of the knob in a clockwise direction caused the metal panel to be displaced to the left while turning the knob in a counter-clockwise direction moved the panel to the right.

Two light-tight boxes were constructed out of wood. The dimensions of each box were 7x 4 x 3.5 inches. The front of each box was covered with a 7- x 3.5-inch sheet of transluscent plastic which was painted flat black. A vertical slit, 3/4 inch high, was etched on the sheets by means of a sharp needle. The slit was located at the center-top of the first box and at the center bottom of the second box. A 40-watt bulb was placed in each box and wired through a transformer to two switches located at the rear of the apparatus. One switch controlled the bulb in the first box and the second switch controlled the light source in the second box. When a switch was activated, light passed through the slit and appeared as an illuminated vertical line.

The boxes were then secured to the main part of the apparatus. The first box was mounted on the plate which was located in the groove of the base. The second box was placed directly on top of the first and was secured to the moveable panel which was attached to the gear assembly. With this arrangement, the illuminated line of the top box could be moved directly above the line of the bottom box by means of the knob located at the front of the apparatus. In addition, the bottom line could be placed at any location to the left of the standard position by inserting a bar between the bottom panel and the metal stop which defined the standard position. In this experiment 6 brass bars with widths of .031, .063, .125, .250, .187, and .375 inch were employed.

A large wooden screen with a 6- x 4-inch aperture cut out in the center was placed directly in front of the apparatus. The aperture was centered so that the illuminated lines were visible to S. A 6-watt bulb which emitted a pinpoint of red light protruded from the right side of the aperture and served as a F-point. This F-point was located .50 inch in front, .25 inch to the right, and .35 inch above the standard position of the bottom line. A half-silvered mirror which was 7 inches high and 6 inches wide was placed directly in front of the aperture in the screen. It was tilted towards the front of the apparatus at an angle of 12 degrees. The purpose of the mirror was to provide a homogeneous ground against which only the two illuminated lines and the F-point were clearly visible.

A vernier caliper was attached to the upper box and to the rear of the wooden screen. With this arrangement any movement of the upper illuminated line could be measured accurately to within .001 inch. A small, shielded reading light was placed above the caliper to enable E to make accurate readings. A head rest which was used throughout the experiment was placed 24 inches in front of the red F-point. The room was illuminated by a 10-watt light bulb which was encased with transluscent plastic and placed on the floor directly behind the apparatus. Room illumination, measured from the position of S's eyes, was approximately .05 foot-candle.

The two vertical lines which were illuminated by 40-watt bulbs set at 75 volts and the red pinpoint of light served both as I- and T-figures. The T-figure was obtained by positioning the bottom line .25 inch to the left of the F-point. This position was previously called the standard position. The upper line was .70 inch above the lower one and, prior to an alignment, was offset .40 inch either to the left or right of the standard position. The I-figure consisted only of the F-point and the bottom vertical line. The I-line could be placed at any of six positions to the left of the standard position. The I- and T-figures are illustrated in Figure 3.

The apparatus for inducing and measuring kinesthetic FAE has been described previously by Howarth (1964). It consisted of 6 blocks of wood which served as I- and T-figures and a comparator. A photograph of the comparator is presented in Figure 4. Each block was 8 inches long and 2 inches high but the widths varied from 2.0 to 4.5 inches in steps of .50 inch. The sides of each block were lined with 8- x 2-inch sheets of brass.

The comparator was an 8- x 6- x 4.5-inch metal box which housed a reversible motor. Two brass bars, each 8 inches long and 2 inches high, were placed parallel to each other on top of the box. One bar was stationary but the other could be moved toward or away from the stationary bar by means of the reversible motor. The direction of movement was controlled by S with a foot

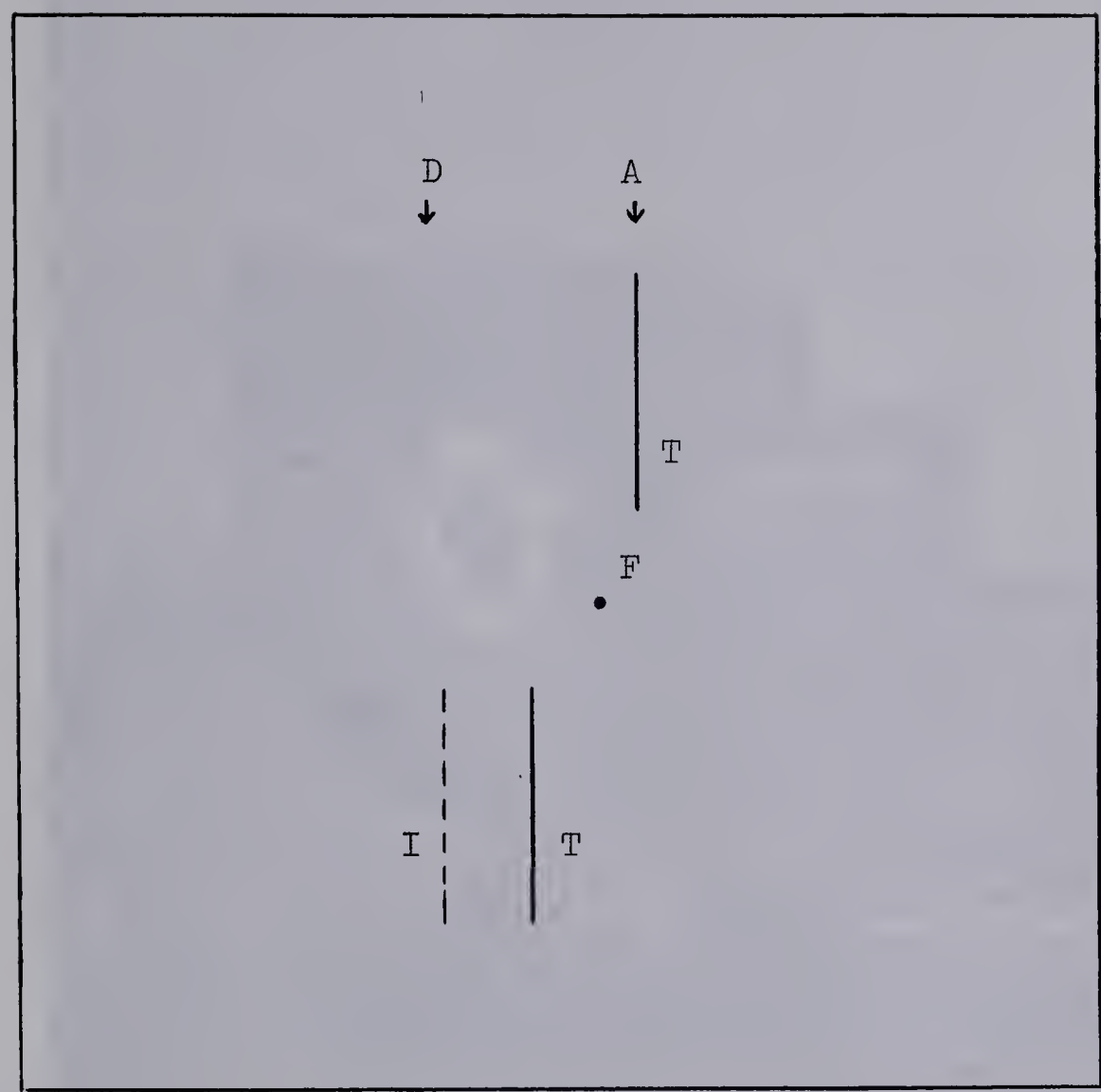

Figure 3. Schematic representation of relationships between inspection-(dashed) line and test-(solid) lines. The variable test-line is shown in the position from which ascending alignments are made. The arrow (D) shows the location of the variable test-line when descending alignments are used.

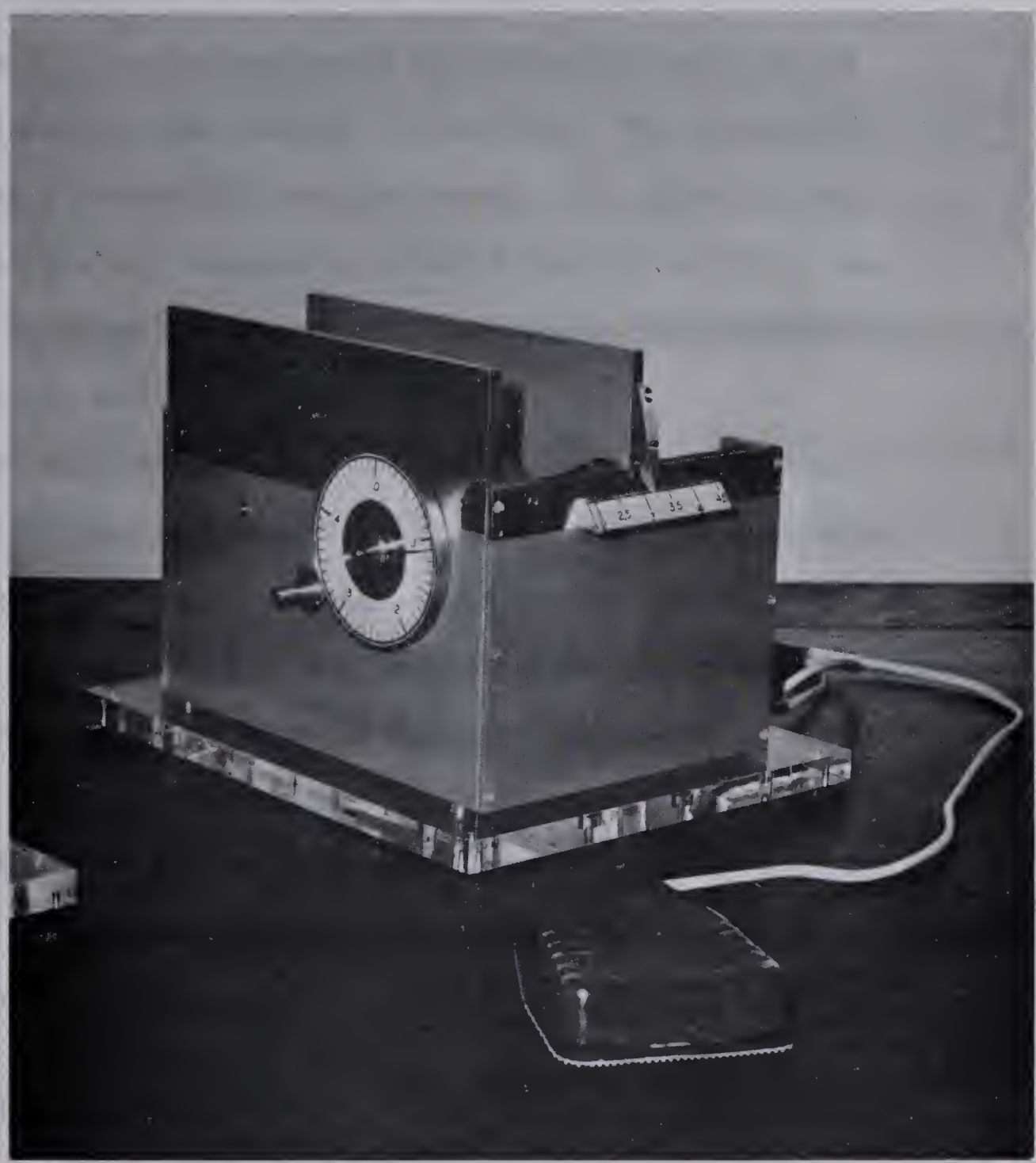

Figure 4. Comparator for measuring kinesthetic width judgments (After Howarth, 1964).

pedal. Depressing the pedal to the left caused the distance between bars to decrease while depressing the pedal to the right increased the distance between bars. The variable bar moved at a rate of .05 inch per second. The exact distance between bars was measured by means of two micrometers located on the sides of the apparatus. Measurements were accurate to within .001 inch.

Two black wooden boxes were placed on either side of a chair. The box on the left was 7 inches high and the one on the right was 11.5 inches high. The seat of the chair was 18 inches above the floor. The comparator was placed on the (S's) left side and was oriented so that the stationary bar was 8 inches away from the chair. The I- and T-blocks were always located on the right side at a distance of 8 inches from the chair. With this arrangement, the wooden blocks and the parallel bars were equidistant from the center of the seat.

Experimental Design

A 7 X 2 X 3 "split-plot" design (Edwards, 1962) was employed for studying the visual FAE. The 7 levels of I-T distance (A) were .000, .031, .063, .125, .187, .250, and .375 inch. Two starting directions (B) were used. That is, prior to each alignment, the upper variable line was offset either to the right

or the left of the bottom line.[1] Finally, there were 3 levels of I-time (C) which were 10, 30, and 50 seconds long.

Ss were assigned at random to each of the A X B combinations, but each S was tested under all levels of C. The order of presenting C was completely counterbalanced within conditions. Twelve such orders were used in each A X B condition and these were assigned at random to Ss. Thus, there were two independent randomization procedures; the first assigned Ss to conditions and the second assigned Ss to order-within-conditions. The only restriction placed on randomization was that an equal number of women and men be tested under each of the A X B combinations.

The kinesthetic FAE was measured under 12 conditions corresponding to a 6 X 2 factorial design. There were 6 levels of I-T distance which were produced by employing blocks of 2.0, 2.5, 3.0, 3.5, 4.0, and 4.5 inches in width. The T-block was always 2.0 inches wide. The 2 I-times were 10 and 50 seconds. A control condition in which an I-block was not presented was also used. Ss were assigned at random to each of the conditions in the order of their appearance at the laboratory. Once again, randomization was restricted so that an equal number of men and women were tested under each condition.

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[1]Hereafter, the term "ascending adjustment" will be used to designate alignments starting from the right of the I-line and the term "descending adjustment" will be used to designate adjustments starting from the left. The rationale for this choice of words is that the position of the I-line defines the distance between that line and the F-point. Consequently, adjustments from the left decrease the distance from the F-point while adjustments from the right increase that distance.

Subjects

Ss were 170 students enrolled in introductory psychology at the University of Alberta, Edmonton. Credit toward the final examination was given for participating in the experiment. One male and one female S were eliminated from the visual FAE study because they failed to comply with instructions. One S was unable to make alignments in peripheral vision and the second did not maintain constant fixation during inspection. Visual FAEs were induced in 168 Ss and kinesthetic FAEs were induced in 156 Ss. An equal number of Ss was assigned to each of the conditions in both visual and kinesthetic tests.

Corrective lenses were worn by all Ss who indicated that such lenses had been prescribed to them. None of the participants was familiar with the phenomena of visual or kinesthetic FAEs.

Procedure

S was led into a normally illuminated room and was asked to sit in a chair which was placed in front of the visual FAE apparatus. The room was then dimmed and the following instructions were given.

> Place your head in the rest and move your chair until you are comfortably seated. Now look ahead and you will notice a red point of light. You will always look directly at this point whenever you are doing anything. And what you will be doing is very simple. (E switched on the lines of light which were placed in the T-position.) Notice two lines of light.

> You are to fixate on the red dot with both eyes and turn this knob in a clockwise (counter-clockwise) direction until the upper line appears to be directly above the lower one. You must make this alignment in peripheral vision. There are three important points that I want you to remember. First, you must always maintain fixation on the red dot and never look directly at the lines. Second, I am not interested in whether the two lines actually are straight, but only where they appear straight to you. They may or may not be really straight. Third, there is a natural tendency to look directly at the lines while you are making your setting and also after you have completed your setting. That is, you may want to find out how well you have done. Do not do either of these things because you will simply become confused and future judgments will be more difficult to make. Therefore, as soon as the two lines appear to form a single straight line, stop turning the knob, close your eyes, and say 'Now.' I will then turn off the lights and you may open your eyes, take your head out of the rest, and relax.
>
> There is just one more point. I would like you to make your adjustments in approximately 8 seconds. Do not spend too much time on each judgment but, on the other hand, be conscientious. Are there any questions? Remember that you must always look at the red dot and, as soon as the lines seem straight, you must close your eyes and say 'Now.'

If there were no questions, E proceeded to give two practice alignments. The purpose of these trials was to ensure that S maintained constant fixation during alignment. One reliable indicator of inadequate fixation is an objectively straight alignment (Prysiazniuk & Kelm, 1963). If S complies with instructions, he will stop before the lines actually are one above the other. A perfect alignment, therefore, is a strong indicator that S is not maintaining fixation. Very few Ss made objectively straight alignments and those who did learned to maintain fixation when E informed them that they were glancing directly at the lines.

A second purpose of the practice trials was to teach Ss to complete their alignments within approximately 8 seconds. If too much time was taken, S was told that he did not require as much time and that a good way to make the setting was to turn the knob rapidly at first and then slow down as the lines begin to appear straight. If the knob was turned too rapidly, S was informed that it would be easier to make the adjustment if he turned the knob at a slower rate.

The time taken to give the instructions and the practice trials was approximately 4 minutes. However, if that length of time had not elapsed, an appropriate rest-period was introduced to ensure that S had adapted to the existent level of illumination.

The main part of the experiment began with two pre-inspection alignments to establish the point of subjective alignment (PSE). The bottom line was placed in the standard position and the upper line was offset .40 inch to the left or right of the bottom line depending upon the experimental condition. Both lines were then illuminated and S adjusted the knob until the lines appeared to be straight. As soon as S said "Now", the lines were turned off, S took his head out of the rest, and E recorded the setting. A rest period of 30 seconds separated the two PSE alignments.

After the second PSE, a 150-second rest was given. During this time the following instructions were given:

> This time you will do something slightly different. I want you to fixate on the red dot and stare at it for a certain length of time. There will be a line in the visual field below and to the left of the F-point but

> you must always look directly at the dot. After a certain interval, I will ask you to place your hand on the knob. Keep looking at the dot, put your hand on the knob, and wait. The top line will then be turned on and you will make a setting just the way you did on the previous trials. Thus, the only difference in this case is that you will stare at the red dot for a certain period of time before you make an adjustment. When you stare, you may blink your eyes on occasion but do not look away from the dot. Are there any questions?

If S understood the instructions, the bottom line was offset to the left of the standard position at a distance defined by the experimental condition. S then placed his head in the rest and fixated on the red dot. The bottom line was illuminated and a stopwatch was activated. During the I-period, the upper line was offset either to the right or left of the standard position. Five seconds before the end of the I-period, S was told to keep looking at the dot and to place his hand on the knob. The bottom line was then replaced in the standard position and, at the same time, the top line was illuminated. S made the appropriate adjustment and his setting was recorded.

Two additional trials measuring the FAE were given in the manner described above except that different I-times were employed. A rest-period of 150 seconds was allowed after each FAE trial. Finally, two more trials measuring the PSE were given. Once again, the interval separating these trials was 30 seconds.

When the test of visual FAEs was completed, the overhead lights in the room were switched on and E sat in the chair located between the kinesthetic comparator and the wooden T-block. The

procedure to be followed was demonstrated while the instructions were given. The S was told:

> Here is one more task that I would like you to do. You will make comparative judgments of width with the thumb and middle finger of each hand. You are to grasp the block of wood with your right hand and the parallel bars with your left hand. Next depress the pedal in front of you either to the right or the left until the distance between the parallel bars is equal to the width of the wooden block. Notice that depressing the pedal to the right increases the distance between the bars while depressing to the left makes the bars come together.
>
> Prior to your adjustment, the variable bars will be offset so that they are too wide or too narrow. Because you will be blindfolded during the test, I will tell you in what direction to start depressing. For example, the bars may be made too wide and I will tell you 'Depress left.' Do you understand what you have to do?

If there were no questions, E continued:

> There are a few more points. When you grasp the block and the bars with the thumb and middle finger of each hand, do not exert more pressure than is necessary to just obtain a feel of the width. If you overshoot the mark during adjustment you may reverse direction. But do not spend too much time on each setting. As soon as your adjustment is completed, place your hands on your lap and relax.

The 2-inch T-block was placed on S's right and the variable T-bar was offset at a distance of 1.5 or 2.5 inches from the stationary bar. Two ascending and two descending trials were given in the order ADAD or DADA. Within each condition the pattern was alternated between Ss in the order of their appearance at the laboratory. The time taken to make a setting by most Ss was between 10 and 20 seconds. If S was still making a judgment after 15 seconds, E prompted a decision by saying. "Is that about it?" The time interval between trials was 30 seconds.

After the last PSE trial, a metronome was turned on at a rate of one beat per second and the following instructions were given:

> Now you will do something different. You will lightly grasp a block of wood between the thumb and middle finger and rub the block back and forth in time to the metronome. Every time a beat comes on you must reverse direction. (E placed S's hand on the 2-inch block and moved it back and forth in order to demonstrate the task.) It is not necessary to cover the entire length of the block--a span of 3 or 4 inches will do. As soon as the metronome stops beating you are to stop rubbing and put your hand on your lap. After this, you will make more judgments of width in the same manner as you did before.

The T-block was replaced by an I-block and S rubbed that block for either 10 or 50 seconds. At the end of the I-period, the I-block was removed and replaced by the T-block. The time required to exchange blocks was about 2 seconds. S then made two ascending and two descending adjustments which were identical in all respects to the trials given prior to inspection.

Ss in the control group were not asked to rub an I-block after the fourth trial. Instead they rested for a period of 90 seconds before continuing with their adjustments.

RESULTS

Visual Figural After-Effect

Initially it was intended that the PSE for each S be established by averaging the two PSE measurements taken before the FAE trials with the two PSEs taken after the FAE trials. However, inspection of the data suggested that on the second set of measurements the T-line was displaced toward the F-point. That is, a residual FAE from the experimental trials was present. Of the 168 Ss tested, 101 exhibited a residual FAE. This number is significantly different from the 84 expected on a chance basis ($\chi^2 = 6.88$; $p < .01$). Consequently, the average of the first two PSE trials only was taken as the estimate of S's true PSE. The FAE was then calculated by subtracting this PSE from each of the alignments that were made immediately after inspection. For each S, FAEs were obtained under I-times of 10, 30, and 50 seconds.

Preliminary analyses.--The first problem was to determine whether or not the method used in the present study yielded significant FAEs. Since the primary characteristic of a FAE is displacement of a T-object away from an I-object, and since in this study the I-line was to S's left of the T-line, a FAE was deemed to be present whenever an alignment was to the right of the PSE. For each S, the three measures of the FAE were

combined and the total number of Ss who showed displacement away from the I-line was calculated. Of the 168 Ss, 122 (64 men and 58 women) exhibited a FAE. This number is significantly different from 84 which is expected on the basis of chance ($\chi^2 = 34.4$; $p < .01$).

A second problem was to ascertain whether the FAE was influenced by sex of S. Two considerations suggested that women performed differently from men on the visual FAE task. The ascending PSEs taken after the experimental trials showed a smaller carry-over effect in female Ss (see Appendix C). In addition, the size of the FAE appeared to be smaller in the female group. For each S, the three measures of the FAE were combined and a t-test was calculated between the means of the two groups. The resulting value of t was 2.01 (df = 166; $p < .05$) which indicates that women had smaller FAEs than men. It was also noted that women were more variable than men but the difference was not statistically significant ($F = 1.32$; $p > .05$). These differences in means and variances prompted the use of separate analyses for the two groups.

Inspection-time and inter-figural distance.--Analysis of variance was performed on the FAE scores from all Ss who participated in the experiment. A summary is presented in Table 1. Increasing I-time produced similar trends in male and female Ss. Figure 5 shows that with descending alignments the FAE increased as a negatively accelerated function of I-time.

TABLE I

SUMMARY OF ANALYSIS OF VARIANCE ON VISUAL FIGURAL AFTER-EFFECT SCORES

Source of Variation	df	Males		Females	
		MS	F	MS	F
A (Distance)	6	.001919	1.98*	.001037	.70
B (Direction)	1	.002833	2.93*	.000087	.06
A X B	6	.000473	.49	.000380	.26
Error	70	.000968		.001484	
C (Time)	2	.000139	.42	.002167	4.53**
A X C	12	.000488	1.47	.000345	.72
B X C	2	.001192	3.58**	.000831	1.74
A X B X C	12	.000266	.80	.000648	1.36
Error	140	.000333		.000478	

*$p < .10$

**$p < .05$

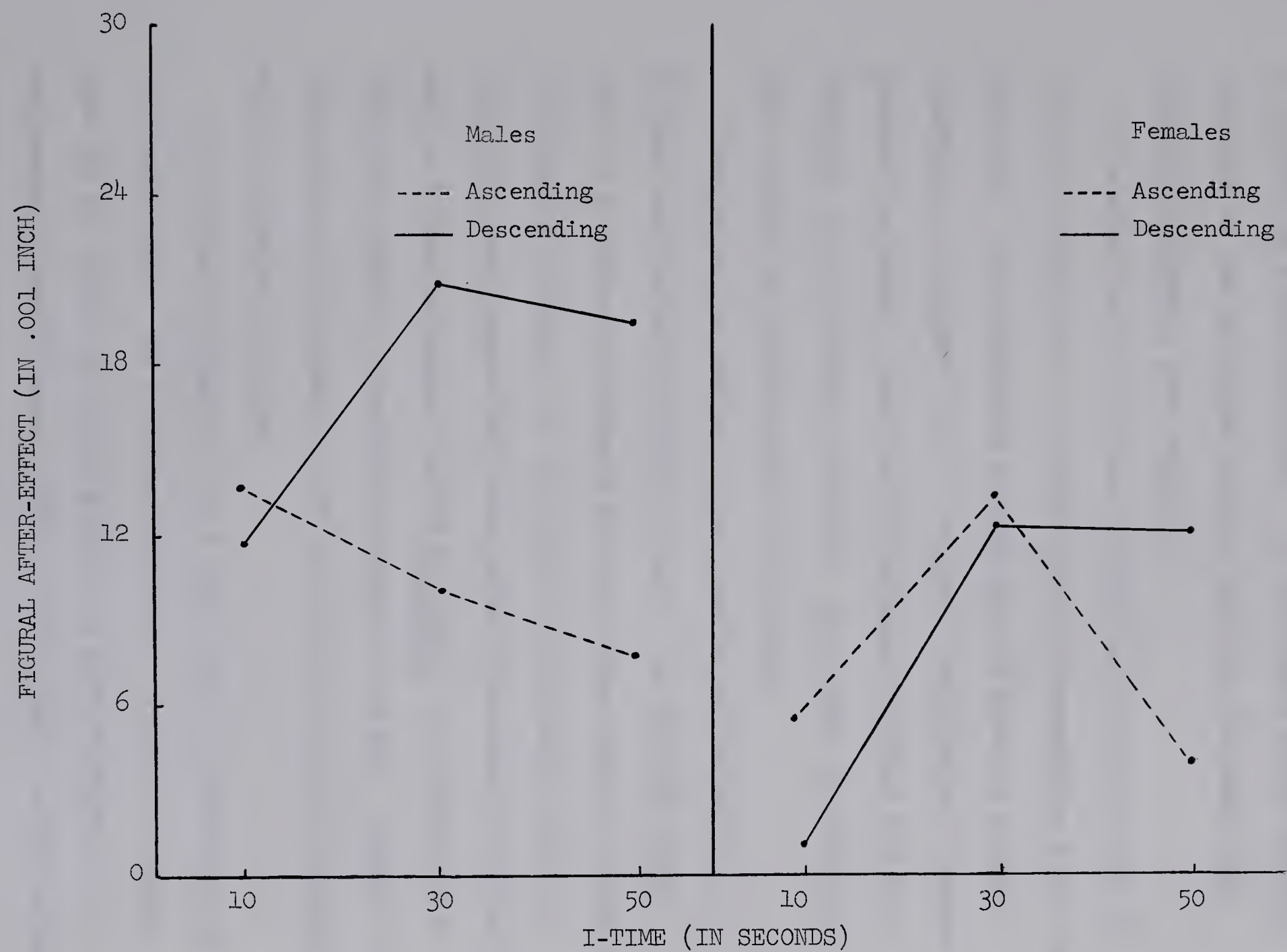

Figure 5. Visual figural after-effects as a function of inspection-time in male and female subjects.

But males who used descending alignments showed a steady decrease in the FAE as I-time increased. In the female group, the FAE increased to the 30-second I-period and then decreased when ascending alignments were employed.

The effect of I-T distance yielded an F ratio of 1.98 (p = .09) for the male group but for female Ss the corresponding F was less than unity. The difference between men and women is clearly observable in Figures 6 and 7. For men, the classical distance gradient is present since the FAE increases at first and then decreases as I-T distance increases. For women, on the other hand, the FAE is invariant with I-T distance.

Changes in the FAE as a joint function of I-time and I-T distance are plotted in Figures 6 and 7. In the male group, there is a systematic tendency for the I-time trend to change as I-T distance increases. At the short I-T distances (.000 and .031 inch), the largest FAE occurs after 10 seconds of inspection and, as I-time increases, the FAE decreases. At a distance of .063 inch, there is a negligible change in the FAE. Finally, at the greatest I-T distances (.125 to .375 inch) the FAE increases with an increase in I-time.

No systematic change in the I-time trend is discernible in the female group. At 5 of the 7 distances, the FAE increases from the 10- to the 30-second period and then decreases. At the remaining two distances (.063 and .375 inch) the FAE increases steadily with increasing I-time.

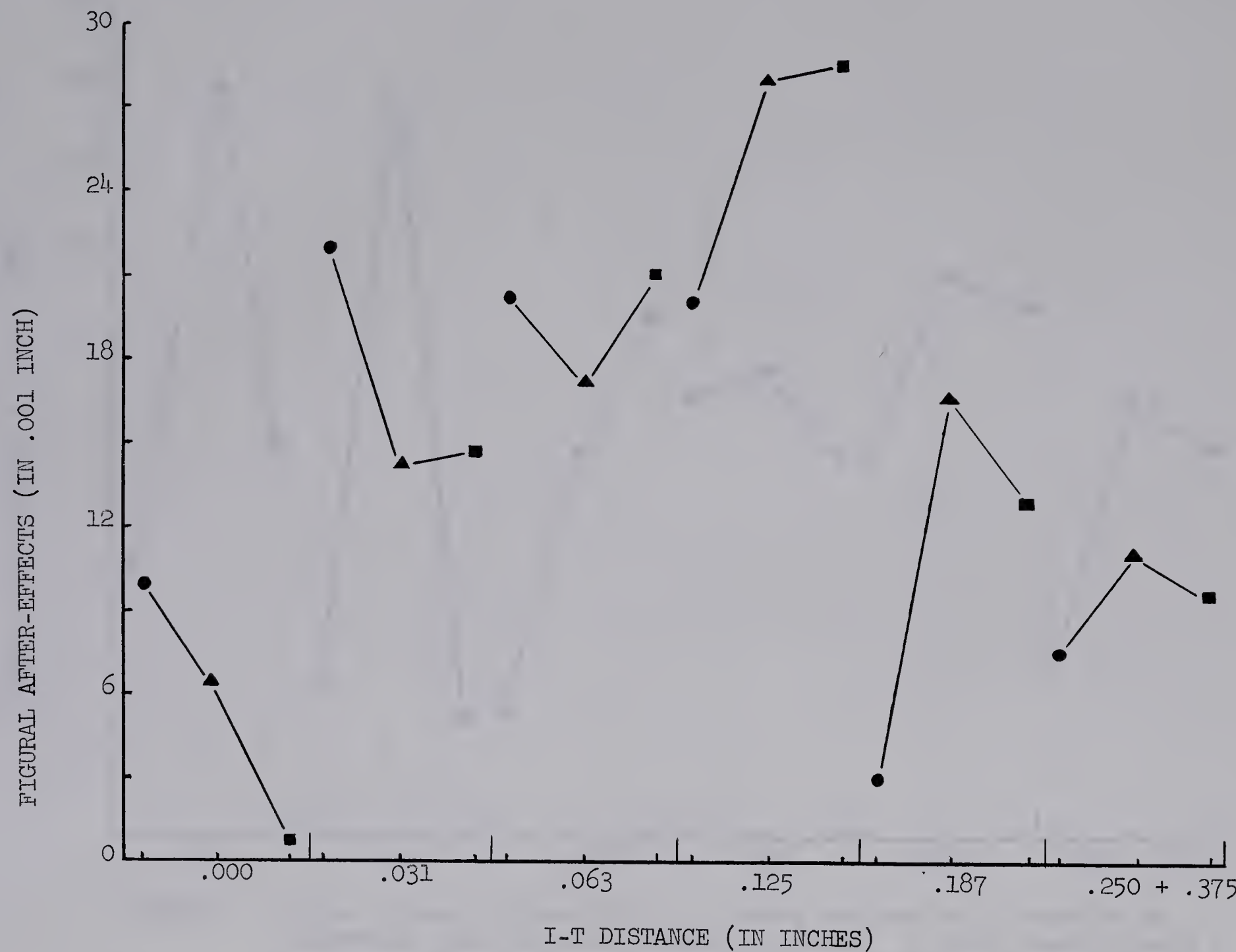

Figure 6. Visual figural after-effects in male subjects as a function of inspection-time and inter-figural distance. In each case a circle represents 10 seconds of inspection; a triangle, 30 seconds; and a sqaure, 50 seconds of inspection. For purposes of presentation, the results from distances of .250 and .375 inch are combined.

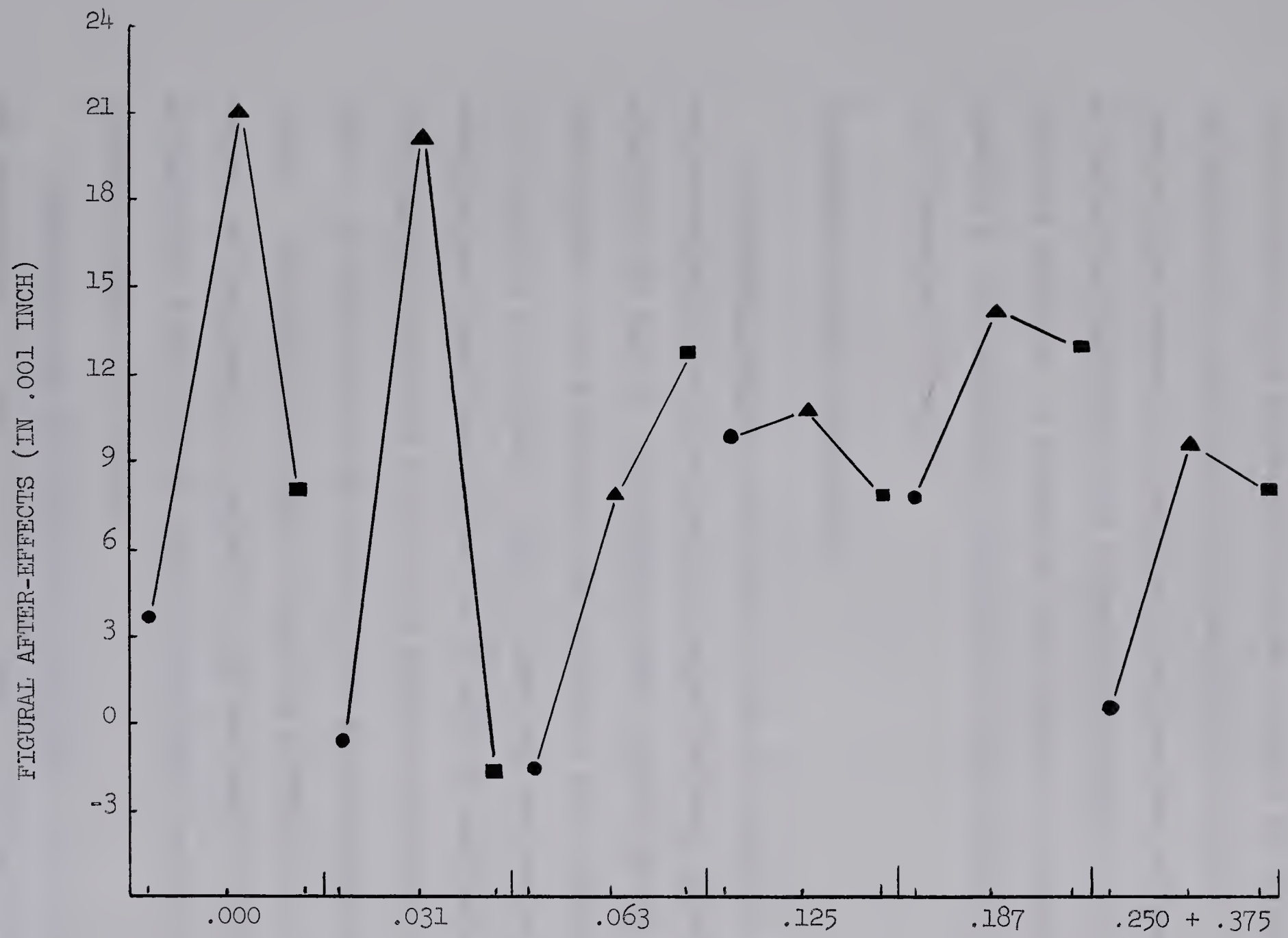

Figure 7. Visual figural after-effects in female subjects as a function of inspection-time and inter-figural distance. In each case a circle represents 10 seconds of inspection; a triangle, 30 seconds; and a square, 50 seconds of inspection. For purposes of presentation, the results from distances of .250 and .375 inch are combined.

It is possible that the use of those Ss in the analysis who did not exhibit FAEs increased the error variance and thus decreased the statistical significance of the manipulated variables. To check on this possibility, analysis of variance was performed only on scores from individuals who evidenced displacement in the predicted direction. A summary of this analysis is presented in Appendix E. The resulting F ratios are not very different from those presented in Table 1.

Kinesthetic Figural After-Effect

Preliminary analysis.--The means of the two ascending and two descending trials given prior to inspection were calculated separately for each S. The resulting PSEs from all Ss who participated in the kinesthetic FAE study were then subjected to an analysis of variance. Table 2 shows that sex and starting direction are significant beyond the 5% level of confidence. Men overestimated the 2-inch T-block to a greater degree than did women. The means were 2.065 and 2.027 for men and women respectively. The significant effect of starting direction is, of course, not surprising. A majority of Es who employ the method of adjustment report that Ss tend to stop before the point of objective equality is reached.

Inspection-time and inter-figural distance.--Two measures of the kinesthetic FAE were obtained for each S. One was determined by subtracting the mean of the adjustments on ascending trials

TABLE 2

SUMMARY OF ANALYSIS OF VARIANCE ON KINESTHETIC POINTS OF SUBJECTIVE EQUALITY TAKEN BEFORE INSPECTION

Source	df	MS	F
Between Subjects	155		
A (Sex)	1	.1080	4.01*
Error	154	.0269	
Within Subjects	156		
B (Direction)	1	17.3980	910.89**
A X B	1	.0360	
Error	154	.0191	

*$p < .05$

**$p < .001$

made after inspection from the ascending PSE which was established prior to inspection. A FAE for descending trials was obtained in a similar fashion. An analysis of variance was performed on the resulting scores. A summary of this analysis is presented in Table 3. Size of I-block (I-T distance), I-time, and starting direction all yielded statistically significant effects.

Changes in the kinesthetic FAE as a joint function of size of I-block and I-time are plotted in Figure 8. It is clear that the kinesthetic FAE increases as a negatively accelerated function of the size of the I-block. The effect of increasing I-time is to increase the asymptotic level of the FAE. That is, differences in the FAE as a function of I-time are negligible when the difference between I- and T-blocks is small but as I-T distance increases the differential effect of I-time increases.

Direction of adjustment.--The effect of direction of adjustment on the kinesthetic FAE is shown in Figure 9. Superficially the results are consistent with Costello's (1963) conclusion that the FAE is larger on descending trials than on ascending trials. But it is instructive to note the performance of the control group. The scores in this group were established in exactly the same manner as in the experimental groups. These scores are very similar in magnitude to the FAEs obtained when I- and T-blocks were of equal width. An analysis of variance comparing the control group with the experimental group which inspected the 2-inch block revealed that the respective ascending and descending

TABLE 3

SUMMARY OF ANALYSIS OF VARIANCE ON KINESTHETIC FIGURAL AFTER-EFFECT SCORES

Source of Variation	df	MS	F
Between Subjects			
A (Distance)	5	.05254	3.60**
B (I-time)	1	.06845	4.69*
D (Sex)	1	.00341	.23
A X B	5	.01041	.72
A X D	5	.01775	1.21
B X D	1	.00963	.66
A X B X D	5	.01944	1.33
Error	120	.01461	
Within Subjects			
C (Direction)	1	.38823	41.84**
A X C	5	.01402	1.51
B X C	1	.00553	.60
C X D	1	.00075	.08
A X B X C	5	.00500	.54
A X C X D	5	.01816	1.96
B X C X D	1	.00728	.78
A X B X C X D	5	.00746	.80
Error	120	.00928	

*$p < .05$ **$p < .01$

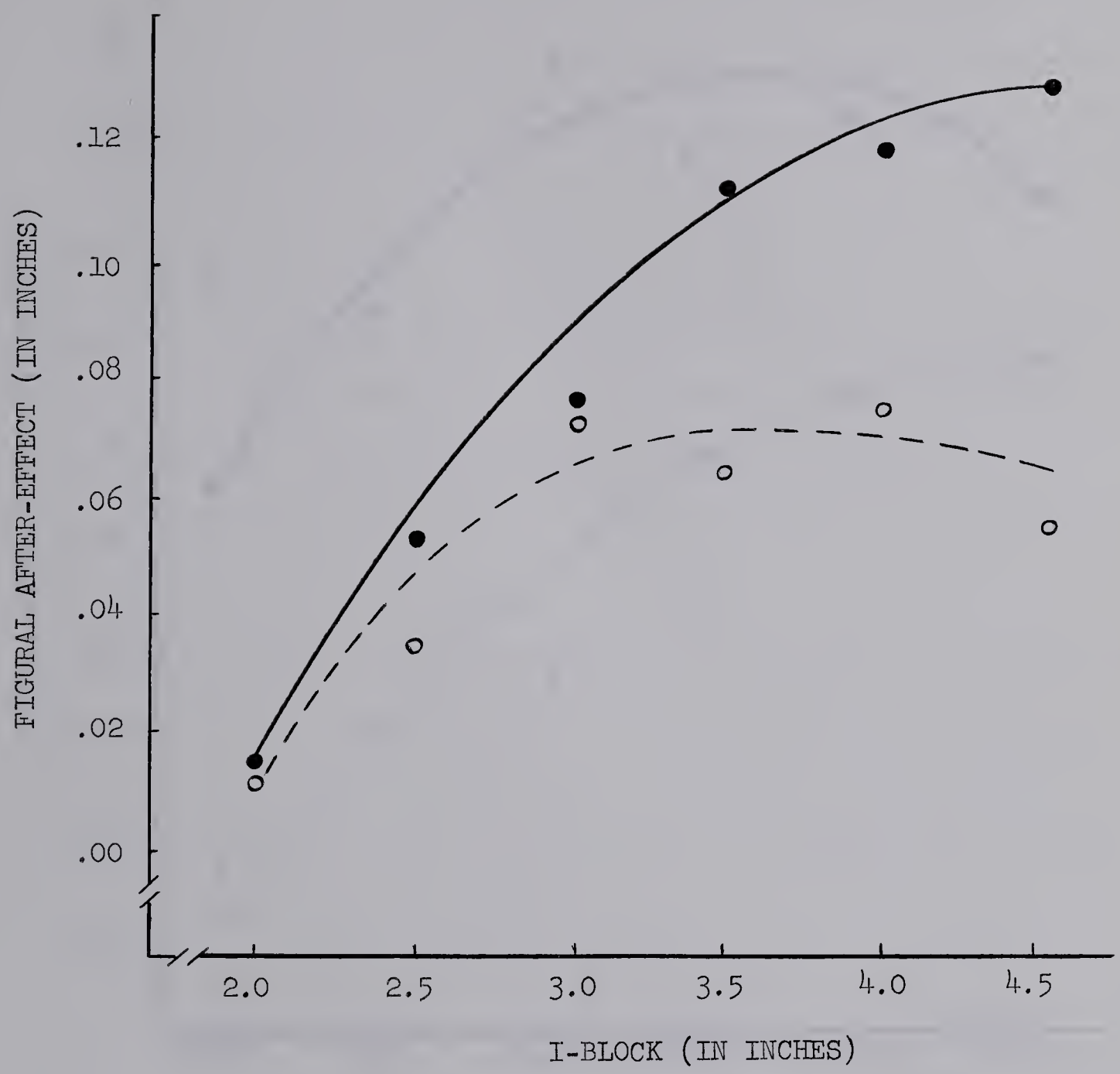

Figure 8. Kinesthetic figural after-effects as a function of inspection-time and width of inspection-block. The broken curve and open circles represent 10 seconds of inspection while the solid curve and filled circles represent 50 seconds of inspection. Curves are fitted by eye.

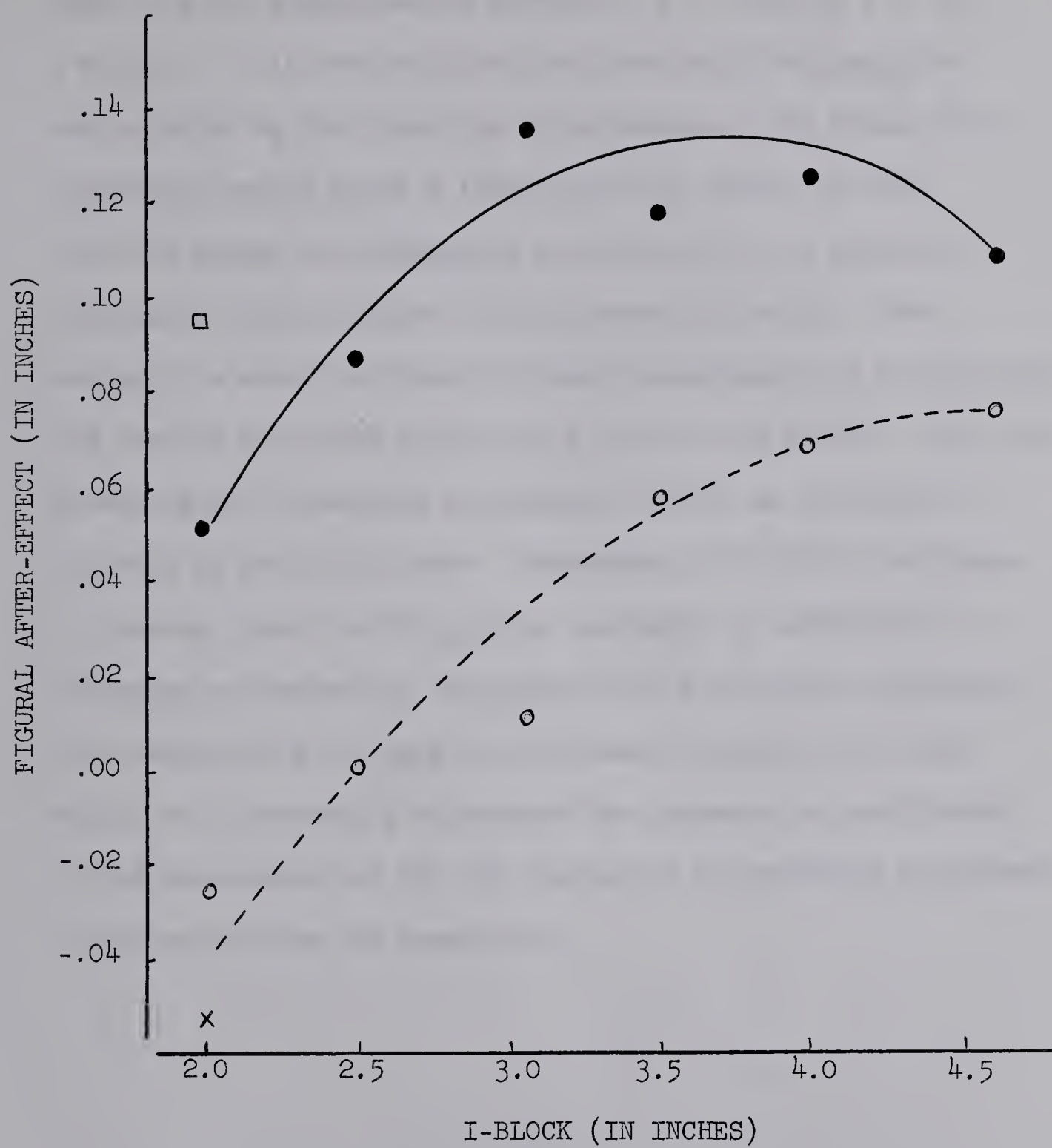

Figure 9. Kinesthetic figural after-effects as a function of direction of adjustment and width of inspection-block. The broken curve and open circles represent ascending adjustments while the solid curve and filled circles represent descending adjustments. The control for ascending trials is designated by a cross and the control for descending trials by a square. Curves are fitted by eye.

FAEs were not statistically different ($F = 1.89$; $df = 1, 34$; $p < .05$). It is obvious that the kinesthetic FAE *per se* is not affected by the direction of adjustment. The reason that descending trials yield a larger over-all effect is that, with the method of adjustment, an increase in the number of successive trials results in an increase in acuity. This tendency is shown in Figure 10 where measurements of the PSE from the control group are plotted as a function of trials. Both the ascending and descending adjustments exhibit an increase in accuracy as trials increase. Therefore, if a FAE of shrinkage is induced, both the FAE *and* the increment in acuity will be reflected on descending adjustments while ascending alignments will reflect the FAE *less* the increase in acuity. In other words, on a descending adjustment the increase in acuity adds to the measurement of the FAE whereas on an ascending adjustment it subtracts from the measurement.

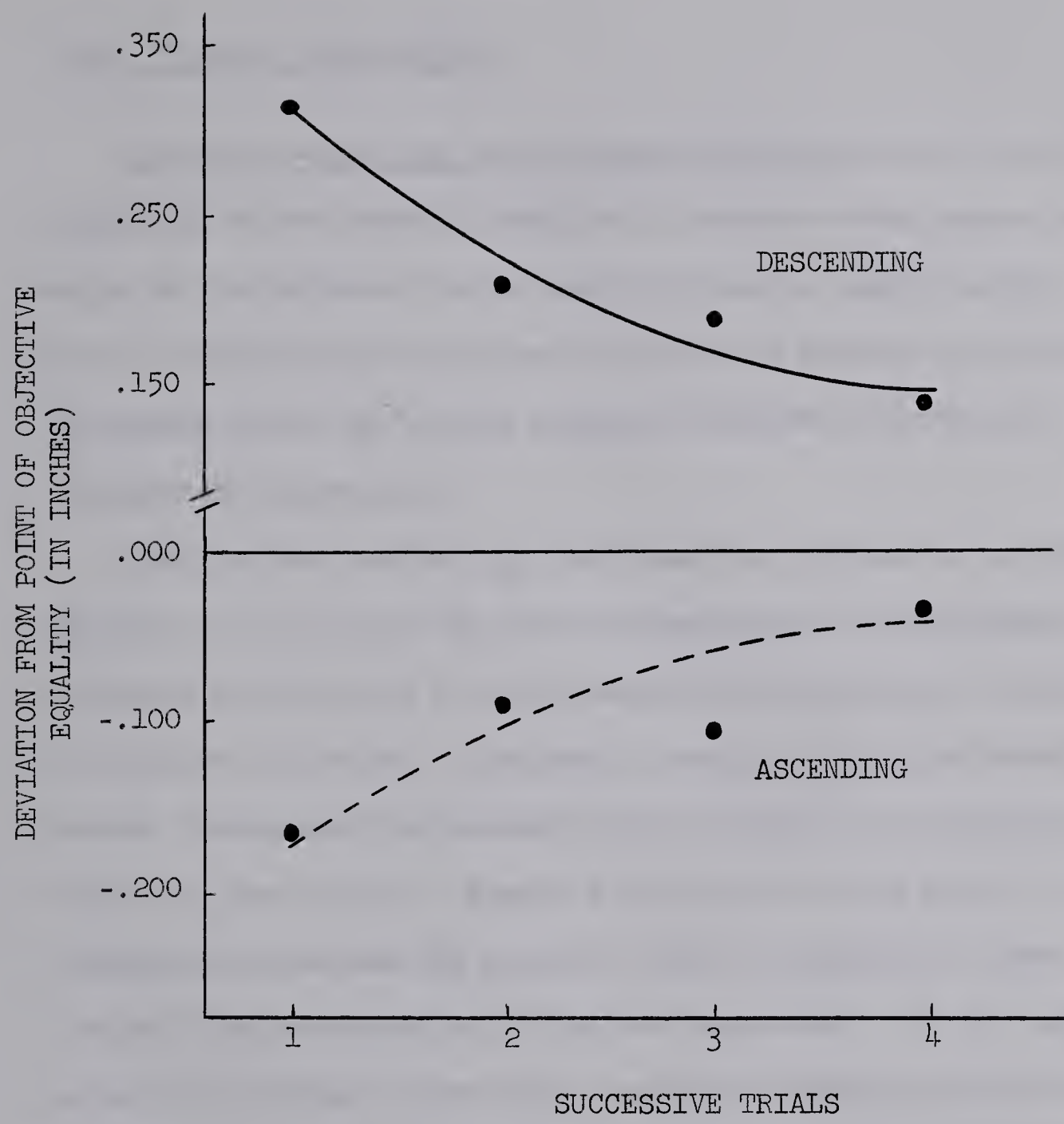

Figure 10. Points of subjective equality of kinesthetic width judgments as a function of successive trials. Curves are fitted by eye.

DISCUSSION

Visual Figural After-Effect

Inspection-time and inter-figural distance.--One of the main objectives of the present study was to determine the manner in which the variables of I-time and I-T distance jointly affect the FAE. Specifically, the aim was to ascertain whether the effect of increasing I-time on the FAE produces different functions at different I-T distances.

Results from the male Ss confirmed the presence of a distance gradient in the visual FAE since the magnitude of displacement increased at first and then decreased with increasing I-T distance. In addition, there was a systematic change in the relationship between I-time and displacement with increases in the distance between I- and T-lines. Figure 6 shows that at the short I-T distances the maximum FAE occurred after 10 seconds of inspection and then decreased as I-time was lengthened. At the intermediate I-T distance there was a negligible change in the FAE as I-time increased. Finally, at the large distances the FAE increased with increasing I-time.

These results are consistent with the hypothesis that the distance gradient in the visual FAE progressively shifts away from the position of the I-figure as I-time is extended. Of the four alternatives presented in Figure 2, the relationships

shown in B and D provide the best fit for the present data. However, it is not possible to make a confident choice between alternatives B and D. The difference between these hypothetical trends is that B depicts the case in which the maximum amount of displacement (at the optimum I-T distance) remains constant as I-time increases, whereas D illustrates the case where the maximum amount of displacement increases with increasing I-time. In the present study the magnitude of displacement for the 10-second I-period at an I-T distance of .031 inch was .022 inch while the FAE for the 50-second I-period at an I-T distance of .125 inch was .029 inch. The fact that the maximum FAE was smaller for the 10-second I-period may be construed as supporting alternative D, but the fact that the difference was not statistically significant ($t = .60$; $p > .05$) detracts from the cogency of this contention. A firm answer to the problem of whether maximum size of the FAE at optimum I-T distance varies with changes in I-time must await future research.

The visual FAE in female Ss was not affected by variations in I-T distance. In addition, the relationship between I-time and magnitude of figural displacement remained the same as I-T distance increased. The lack of a distance gradient in women may be due to a sampling error or it may represent a reliable finding. If the latter alternative is correct, this would necessitate a revision of every existing theory of FAEs since all these theories assume the presence of a distance gradient

in every individual. But before such a drastic theoretical revision is adopted, the reliability of this finding should be ascertained. Future studies, employing a wide variety of configurations and psychophysical methods, are necessary to determine whether or not a distance gradient is present in female Ss.

It was contended earlier that different investigators reached different conclusions regarding the relationship between I-time and FAE because I-T distance was not controlled. The results from the male Ss support this view because the I-time trend did vary markedly with changes in I-T distance. This fact has one major implication for future investigations of FAEs, viz., that a multi-variable rather than a single-variable approach must be adopted. That is, effects of several independent variables on the FAE must be determined simultaneously. Such a procedure will ensure that conclusions about FAEs will have at least some generality.

The importance of measuring the FAE under different combinations of variables can be illustrated with two examples. Gibson (1933) and Köhler & Wallach (1944) claimed that the magnitude of figural displacement is reduced by about 50% when one eye is used for inspection and the alternate eye for testing. But only one I-time and one I-T distance was sampled by each investigator. It is possible that use of several I-T distances would show that what is changed is not the maximum size of the FAE but rather the distance between I- and T-figures that yields a maximum FAE.

If this were the case, then the simple conclusion that interocular transfer reduces the FAE would have to be modified. A second example is based on the work of Spitz & Blackman (1959) and Prysiazniuk & Kelm (1963) who concluded that the FAE in mentally retarded adults is smaller than that of normal Ss of the same mental age. Once again the samples of I-time and I-T distance were insufficient to exclude the alternative hypothesis that it is optimum I-T distance and not the maximum size of the FAE that is different in retarded Ss. Many other examples may be brought out but these suffice to show that the generality of past conclusions about FAEs are suspect because independent variables were inadequately sampled.

Sex differences.--The large sex difference present in this study confirms Wertheimer's (1954) report that women are less susceptible to a visual FAE than men. However, Wertheimer interpreted his findings to mean that women differ only in the rate at which the FAE develops and that, given a large enough I-time, the sex difference disappears. These data do not support Wertheimer's interpretation. Combing scores for ascending and descending alignments in Figure 5 indicates that women have a smaller FAE than men at all levels of I-time. Furthermore, it cannot be argued that the 50-second I-period was not long enough to allow women to reach an asymptote since the FAE decreased from the 30- to the 50-second I-period. The correct interpretation appears to be that both the rate of

development and the asymptotic level of the visual FAE are lower in women than in men.

The presence of a sex difference is difficult to incorporate into most of the existing theories of visual FAEs. There is no independent theoretical construct in the theories of Osgood & Heyer (1952), Deutsch (1964), Gibson (1933) or Helson (1964) to explain the fact that FAEs develop at a slower rate and reach a lower level in female Ss. However, Köhler & Wallach's (1944) theory does contain an independent construct and that is the concept of "statistical satiation." Statistical satiation refers to a relatively permanent state of homogeneous electrotonus that exists in the cortex. It is permanent because it results from the normal activity of the cortex and is homogeneous because it is not characterized by gradients such as those which result from prolonged inspection of circumscribed contours. If it is postulated that the basal level of permanent satiation varies, it follows that there will be an inverse relationship between the basal level and (a) the rate of development of subsequent satiation and (b) the maximum level to which satiation can develop. Temporary satiation will develop at a slower rate because satiation is a self-limiting process. Thus, the greater the basal level of permanent satiation, the smaller is the increment of temporary satiation per unit time. Similarly, the relationship between level of permanent satiation and level of temporary satiation will be an inverse one. For, if there is

some level beyond which satiation cannot increase, and if the level of permanent satiation is high, then the level of temporary satiation must decrease.

Sex differences are explicable on the basis of satiation theory if it is assumed that women are characterized by higher basal levels of satiation than men. FAEs in female Ss would increase at a slower rate because I-time would produce smaller increments in temporary satiation. In addition, the asymptotic level of figural displacement would be lowered because the absolute level of temporary satiation would be smaller.

Although the hypothesis that the FAE is affected by the basal level of satiation is promising, it cannot be evaluated at the present time because of the paucity of relevant empirical data. Moreover, the data that do exist are not consistent. Howarth (1958) measured the FAE immediately after awakening and in the evening and found that the effect was greater in the evening. This, of course, contradicts Köhler & Wallach's theory since it would be predicted that the basal level of satiation would be lower in the morning and consequently the FAE would be larger. On the other hand, the present investigator (Prysiazniuk, 1962) recorded the magnitude of figural displacement following 12, 36, 60, and 72 hours of sleep deprivation and found a systematic decrease in the FAE as sleep deprivation increased. This result is consistent with satiation theory since sleep deprivation should increase the basal level of satiation and thus decrease the magnitude

of displacement. Further investigations must be carried out to establish how variables such as I-time and I-T distance interact with basal levels of satiation. Such research would establish the extent to which individual differences in the FAE are dependent upon differences in the level of permanent homogeneous satiation.

Direction of adjustment.--One of the most puzzling trends found in this experiment is that the effect of increasing I-time on the visual FAE depends upon the direction from which adjustments are made. Figure 5 shows that with descending alignments the FAE increases as a negatively accelerated function of I-time but with ascending alignments the FAE tends to decrease with I-time. The simplest explanation for the different relationships is that I-time produces changes not only in the location of a contour but also in visual acuity. On descending alignments increased acuity is manifested by settings which are closer to the point of objective alignment, i.e., towards the F-point. Since the induced FAE is also in the same direction, the two processes summate to yield progressively larger effects. But with ascending alignments increases in acuity manifest themselves in settings which are away from the F-point. In this case, the increase in acuity subtracts from the total effect. Except for one major difference, this analysis is similar to the one presented earlier to explain the effect of direction of adjustment on the kinesthetic FAE. The difference is that kinesthetic judgments

of width increase in acuity as a simple function of practice whereas visual acuity increases only after S has inspected the I-line for a prolonged interval. That it is I-time, and not practice, which is responsible for the increase in acuity is supported by two considerations. First, the order of presenting I-times was completely counterbalanced with the result that there was an equal number of 10-, 30-, and 60-second I-periods on each trial. Second, a plot of the 4 PSE trials (2 practice and 2 experimental) taken prior to the I-condition showed no tendency for the settings to approach the point of objective alignment (see Appendix F). Both ascending and descending alignments remained constant with an increase in the number of successive trials. This trend contrasts sharply with that of the kinesthetic width judgments shown in Figure 10. One conclusion that can be drawn from these results is that prolonged inspection decreases the ability to localize a contour in space but, at the same time, increases the ability to resolve that contour.

The theories of Köhler & Wallach (1944), Deutsch (1964), Helson (1964) and Gibson (1933) are not capable of explaining the fact that acuity increases with increasing pre-inspection of another object simply because acuity is beyond the bounds of their theories. But Osgood & Heyer's explanation of FAEs is based on a theory of contour resolution and thus may be evaluated in relation to the present findings. Statistical

theory claims that a contour is represented in Area 17 as a Gaussian distribution of excitation and that the location of the contour in subjective space corresponds to the peak of excitation. If this peak is sharply delimited, the contour will be clearly perceived, but if the gradient is relatively diffuse the percept will be blurred. But Osgood & Heyer also claim that the excitation gradient around a line which lies in a heavily adapted region will be flatter (more platykurtic) than normal. This would imply that a contour would appear blurred after inspection of another contour. Acuity would thus be expected to decrease and not to increase as found in the present study.

Additional considerations.--In some respects the data on the visual FAE are perplexing. For example, Appendix D shows that the distance gradient for PSEs taken after the experimental session is statistically significant. It is clear that the FAE failed to dissipate in the 150-second rest period that was provided after the last experimental trial. In this respect the results do not conform to previous studies which found that the FAE dissipated completely after approximately 60 seconds of rest. However, the failure of a FAE to dissipate is not without precedent. Duncan (1962) found that with a 60-second I-period there was no reduction of the FAE even after 5 minutes of rest. No explanation was offered for this phenomenon but one possibility is that the rate of dissipation depends upon the subjective dimension that is distorted. After-effects of distance or size may

dissipate at a much slower rate than after-effects of shape or orientation. This hypothesis would explain the results of Duncan's experiment and also the present findings. A common factor underlying both studies is that the response variable can be classified as a change in distance. Duncan measured changes in the distance between two vertical lines following inspection of a vertical bar placed between them. In this study the criterion was displacement of a vertical line towards a F-point which can also be classed as a variation in the distance between objects.

There is some empirical support for the notion that dissipation of the FAE varies with the subjective dimension that is distorted. Pick, Hetherington & Belknapp (1962) found that an after-effect of size failed to dissipate after 30 minutes provided that S was blindfolded or viewed a ganzfeld during the rest-period. On the other hand, an after-effect of curvature was not present after 15 minutes nor could it be maintained by blindfolding S or by having him view a ganzfeld. These findings strongly suggest that variations in the type of stimulus that is used to produce FAEs can result in different empirical relationships and that the failure of the FAE to dissipate in the present study may be due to the type of configuration that was employed.

Another result which is difficult to reconcile with previous research is that only 72% of the Ss exhibited visual figural

displacement. Although this percentage is highly significant statistically, it is well below the proportions found by Hammer (1949) and Kelm (1960) who used a method which was very similar to that of the present study. A possible reason for the smaller number of Ss evidencing displacement in this experiment is that naive Ss were used whereas Hammer and Kelm employed experienced graduate students. It may be, as McEwan (1958) points out, that observational difficulties are so great that naive Ss are unduly influenced by attitudinal factors such as their feeling that they ought to "get the right answer." In this respect, the use of naive Ss is detrimental to the investigation of FAEs. On the other hand, the repeated use of the same S is also subject to criticism particularly if multi-variable designs are employed. The degree to which one measurement of a FAE affects subsequent measurements has not been thoroughly investigated. And, as the present findings show, the technique of interpolating long rest periods between measurements does not ensure that all carry-over effects will be eliminated. For these reasons, a randomized-groups design is preferable to a repeated-measurements design. A simply solution to this methodological problems lies in the use of a stimulus configuration that produces a large and reliable effect in naive Ss.

Kinesthetic Figural After-Effect

The data on the kinesthetic FAE shown in Figure 8 indicate that the classical distance gradient is not present. The FAE

increases as a negatively accelerated function of the size of the I-block. There is no tendency for the FAE to decrease when the largest I-blocks are employed. It cannot be argued that a decrease would have been in evidence had still larger I-blocks been used because 4.5 inches is very near to the maximum span between the thumb and middle finger. Consequently, the results strongly favour the view that the decreasing portion of the classical distance gradient does not occur in the after-effect of kinesthetic width judgments.

The absence of a distance gradient in the present study immediately raises questions regarding the basis upon which Charles & Duncan (1959) and Krauskopf & Engen (1960) concluded such gradients are present. Since these investigators also used kinesthetic width judgment as their independent variable, it seems likely that the contradictory conclusion does not lie in the type of attribute that was distorted. A close examination of Charles & Duncan's and Krauskopf & Engen's experiments suggests that, in the former case, measurement of the FAE was confounded while the latter investigators misinterpreted their results.

Charles & Duncan used a single I-block which was 2 inches wide and several T-blocks which varied in width from .125 to 2.0 inches. The I-block was presented for 60 seconds. Their results showed that the amount of shrinkage of the T-blocks increased at first and then decreased as the width of the T-blocks decreased. But the procedure of varying T-block instead of I-blocks to

increase I-T distance is subject to criticism. Small T-blocks will not shrink as much as large ones regardless of the distorting conditions because different "ceilings" are involved. For example, whereas a 2-inch width may shrink more than .25 inch (see Appendix B), a .125-inch T-block cannot shrink more than .125 inch. This difference alone could cause FAEs to decrease when very narrow T-blocks are used. Charles & Duncan could have overcome this difficulty, at least partly, by taking the relative instead of the absolute amount of shrinkage as their measure of the size of the FAE. Their scores would then be expressed as percent decrement in width. When such a transformation is performed (Appendix G), it is difficult to argue that a distance gradient is present. A decrease in the FAE occurs only at the smallest T-width.

Krauskopf & Engen employed a 2-inch T-block and 5 I-blocks which ranged in width from 2.5 to 4.5 inches. The largest FAE was present when the I-block was 4.0 inches and the FAE decreased when the 4.5 inch I-block was used. They interpreted this final decrement to mean that a distance gradient, formally similar to the one found in vision, is also present in the kinesthetic FAE. But Krauskopf & Engen's conclusion is unconvincing because they failed to find a gradual increase in the FAE as I-widths increased from 2.5 to 3.0 to 3.5 inches. Moreover, the largest (4.5-inch) block yielded a much greater FAE than the first three I-blocks. Hence, their data appears to fit a linear trend just as well or better than, a quadratic one. Unfortunately, a trend analysis

was not performed so that agreement or disagreement with Krauskopf & Engen's conclusion must be based on visual inspection rather than on statistical probabilities.

Theories of Figural After-Effects

It was stated earlier (p. 46) that Köhler & Wallach's satiation theory offers the best explanation of FAEs but that one of its weaknesses lies in the fact that it does not provide a precise enough description of the manner in which satiation develops around a contour as I-time is prolonged. Furthermore, it was contended that satiation theory could be revised and amplified in strict accordance with empirical findings. The results from the visual FAE test of the present experiment can provide a basis upon which such revision and amplification can be carried out. One of the main findings was that the optimum distance between I- and T-contours increased as I-time increased. If Köhler & Wallach are correct in assuming that it is the differential level of satiation which is responsible for displacement, it follows that the distance at which differential level is greatest increases with I-time. A schematic representation of the type of changes that occur in intensity of satiation at various distances from the inspected contour is presented in Figure 11. Intensity of satiation is represented on the ordinate and distance from inspected contour is represented on the abscissa. It can be seen that, after a short I-period, satiation is of

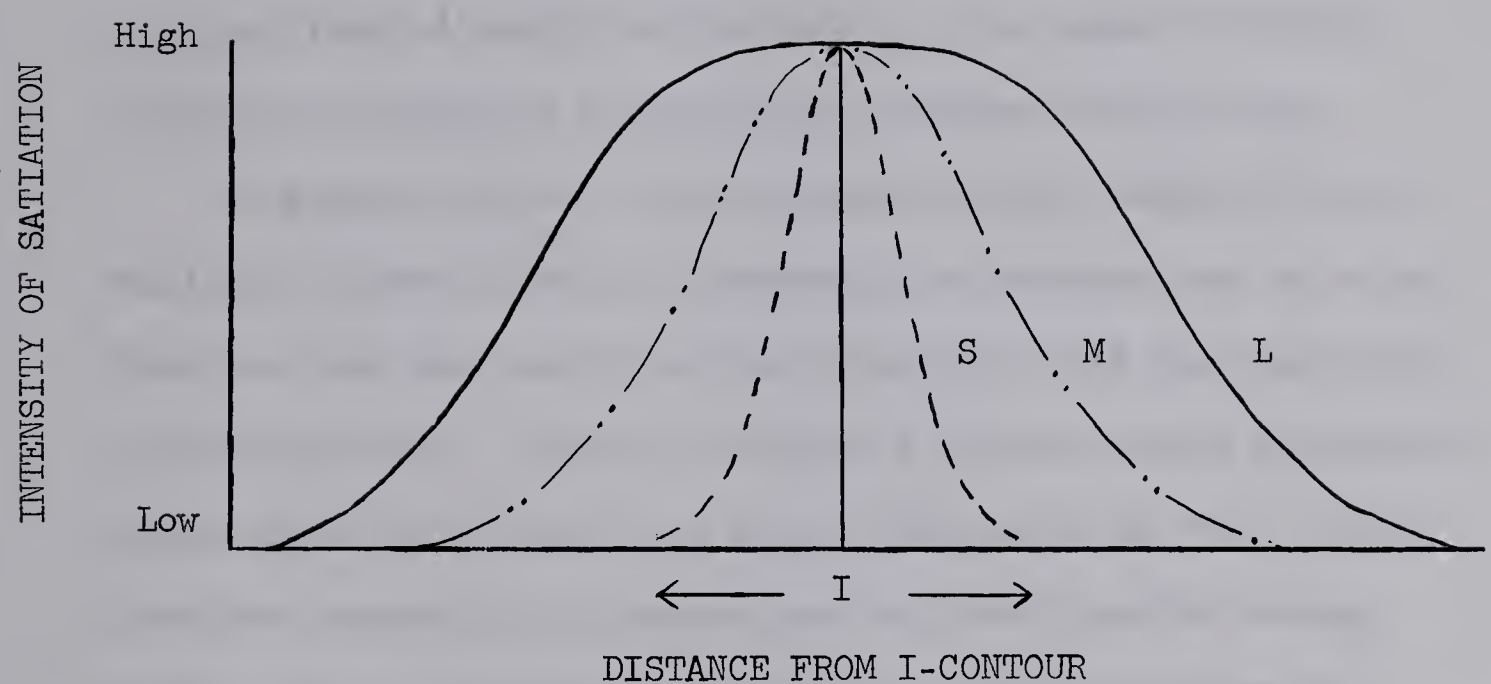

Figure 11. Hypothetical changes in pattern of satiation around an I-contour as a function of short (S) medium (M) and long (L) inspection-times.

maximum intensity at the contour and the degree of spread around the contour is not very great. After a long I-period, on the other hand, satiation spreads further and, even at some distance from the contour, intensity is relatively high. It should also be noted that, directly at the contour, the extent to which satiation is high but ungraded also increases with I-time.

It might be argued that the above analysis makes Köhler & Wallach's theory capable of subsuming the present data on visual FAEs but that the results on the kinesthetic FAE test contradict satiation theory. Indeed, if Köhler & Wallach accept kinesthetic after-effect as a fact lying within the limits of their theory, then the absence of a distance gradient does provide strong evidence against their theory. Implicit in the concept of satiation is the view that there is a definite limit to the extent to which satiation spreads beyond the region of maximum excitation. Regions well beyond the point of excitation are assumed to remain relatively unaffected. If the formal structure of satiation theory is to be applied to kinesthesis, it would have to be argued that satiation in the kinesthetic cortex must also be limited and that, therefore, a distance gradient should occur.

Satiation theory can overcome the difficulties presented by kinesthetic FAEs by contending that such after-effects do not reflect satiation processes but some other factors. That is, it can be assumed that what is measured by current methods is not satiation but rather some processes which manifest themselves in a superficially similar fashion to satiation. Although

this may appear to be an unsatisfactory way of rescuing the concept of satiation, it is not entirely an unreasonable approach. For example, it may be pointed out that, when visual and kinesthetic FAEs are measured on the same scale, the latter FAEs are approximately ten times the size of the former. If visual FAEs represent a fair approximation of the effects of satiation, then what is measured by the kinesthetic FAE task may mask the effects of satiation. In other words, it is still possible that a distance gradient would be found in kinesthesis if satisfactory techniques for eliminating additional factors and measuring satiation accurately could be found.

It is clear from the above considerations that a two-factor approach to the FAE phenomena is being advocated. Satiation-like processes are presumed to be most salient in visual FAEs while other factors are assumed to be most salient in kinesthetic FAEs. Indeed, at the present stage, it would be desirable to conceptually differentiate between visual and kinesthetic FAEs by using different labels for the two phenomena. An obvious possibility is to retain the term "figural after-effect" for visual distortions and to call other distortions simply "after-effects."

If a two-factor approach is adopted, a question that immediately arises relates to the nature of this additional factor. Specifically, the problem is to explain the phenomenon of kinesthetic after-effect as measured in this and previous

investigations. The most fruitful approach appears to lie in frame of reference theories, particularly Helson's (1964) adaptation level theory. Helson states that judgments of magnitude are always made in relation to a momentary indifference point which is termed "adaptation level." Adaptation levels increase whenever strong stimuli (anchors) are introduced and decrease whenever weak anchors are presented. The fact that a narrow width appears narrower after stimulation from a larger width is because the large width shifts adaptation level upward. When the narrow width is re-introduced, it is judged in relation to the new adaptation level and thus is perceived as narrower than it was prior to stimulation.

It cannot be denied that some simple facts, such as direction of distortion of kinesthetic judgments, can be subsumed under Helson's theory. However, the key question that is prompted by the present experiment is whether extremely large anchors have the same effect as intermediate anchors or whether adaptation level is relatively unaffected by extremely large anchors. To put it more simply, the question is whether adaptation level theory predicts a monotonic or non-monotonic relationship between I-T distance and kinesthetic FAE. Helson himself is not clear on this point because he states that an anchor may be so very different from the existing adaptation level that it may fail to affect that level. But this statement lacks theoretical import because it does not provide an independent

operation by means of which one can establish when an anchor will be effective and when it will not be effective. Consequently, Helson's theory, as it now stands, does not allow an unambiguous prediction to be made regarding the relationship between I-T distance and the kinesthetic FAE.

In contrast to the theoretical vagueness, the empirical data is in agreement on the effects of increasing size of an anchor on magnitude of judgmental shifts. It has long been known that categorical judgments shift systematically whenever an extreme stimulus is introduced into a series. Guilford (1954) summarized the work of several investigators (Cohen, 1937; Hunt & Volkmann, 1937; McGarvey, 1943; Postman & Miller, 1945; and Volkmann, 1936) who were concerned with the relationship between magnitude of anchoring stimuli on degree of judgmental shift. He concluded that:

> a. The farther the anchor stimulus from the stimulus range, the greater the shift.
> b. The more remote the anchor stimulus, the less the increment of shift. By this is meant that the shifting effect shows diminishing returns.

It is evident that these statements describe precisely the relationship between size of I-block and magnitude of kinesthetic FAE found in this study. The hypothesis that kinesthetic aftereffects result from a change in the frame of reference is, therefore, supported.

A Final Comment

The view that kinesthetic after-effects are produced by a shift in a frame of reference challenges the use of kinesthetic after-effects to test neurophysiological hypotheses. There are several examples of such tests in the literature. Klein & Krech (1952) argued that larger kinesthetic after-effects in brain-damaged patients supported their theory that brain-damaged individuals are characterized by decreased cortical conductivity. Eysenck (1955) interpreted the fact that extraverted individuals exhibited larger kinesthetic after-effects then introverts was consistent with his hypothesis that extraverts develop reactive inhibition more rapidly than introverts. Finally, Spitz & Lipman (1961) contended that smaller kinesthetic distortions in retardates supported the view that such Ss are less satiable than normals. In light of the present study, it is plausible to argue that these investigators measured group differences in the capacity to shift a frame of reference rather than differences in electro-chemical cortical activity.

SUMMARY

Visual and kinesthetic figural after-effects were determined as a joint function of inter-figural distance and inspection-time. Visual figural displacement was induced in 168 Ss under 7 inter-figural distances and 3 inspection-times. A large sex difference was found. Women exhibited a smaller degree of displacement than men. Results from male Ss indicated that the inter-figural distance which yielded maximum displacement increased as I-time increased.

Kinesthetic figural after-effects were induced in 144 Ss under 6 inter-figural distances and 2 inspection-times. The classical distance gradient was not evident. Rather, the after-effect increased as a negatively accelerated function of inter-figural distance. Increase in I-time produced an increase in the asymptotic level of after-effect.

The results were discussed in relation to existing theories of figural after-effects.

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APPENDICES

APPENDIX A1

Raw Scores (in Inches) on the Visual Figural After-Effect Test at an Inter-Figural Distance of .000 Inch

Subject	Sex	Direction	Order	Inspection-Time		
				10	30	50
11	F	A	30-50-10	.003	.031	.017
76	F	A	50-10-30	.013	.058	.009
87	F	A	10-30-50	-.053	-.008	.002
122	F	A	10-50-30	.023	.043	.019
131	F	A	50-30-10	.024	.025	.009
143	F	A	30-10-50	.026	.014	.001
32	F	D	50-10-30	-.010	.016	-.056
49	F	D	10-50-30	-.034	.007	.067
58	F	D	30-50-10	.037	-.005	-.008
65	F	D	10-30-50	-.020	-.036	.033
107	F	D	30-10-50	.036	.018	.000
123	F	D	50-30-10	.005	.085	.004
2	M	A	10-50-30	-.029	.001	-.065
20	M	A	10-30-50	-.011	.011	.006
50	M	A	30-10-50	.022	.022	.016
59	M	A	50-30-10	.032	.002	-.019
93	M	A	30-50-10	.012	-.027	.002
150	M	A	50-10-30	-.005	-.010	.005
6	M	D	30-10-50	.023	-.010	-.005
13	M	D	50-30-10	.029	.030	.024
89	M	D	50-10-30	.034	.054	.038
135	M	D	10-50-30	.020	.026	.026
145	M	D	30-50-10	.006	-.028	-.018
158	M	D	10-30-50	-.016	.012	-.008

APPENDIX A2

Raw Scores (in Inches) on the Visual Figural After-Effect Test at an Inter-Figural Distance of .031 Inch

Subject	Sex	Direction	Order	Inspection-Time		
				10	30	50
9	F	A	10-50-30	.020	.029	.020
45	F	A	30-10-50	.003	.003	.003
102	F	A	10-30-50	.006	-.022	-.042
108	F	A	30-10-50	-.016	.029	.010
112	F	A	30-50-10	.000	.060	.002
166	F	A	10-50-30	-.006	-.002	-.006
3	F	D	30-10-50	-.018	-.009	-.033
18	F	D	50-30-10	.004	.054	.057
74	F	D	50-10-30	.006	.018	-.030
82	F	D	10-30-50	.028	.026	-.014
106	F	D	50-10-30	-.074	.013	-.052
111	F	D	50-30-10	.031	.040	.056
33	M	A	50-10-30	.011	.001	-.025
44	M	A	10-30-50	.037	.009	.022
63	M	A	50-30-10	-.021	-.025	-.016
81	M	A	30-50-10	.067	.016	.040
139	M	A	50-30-10	.034	.002	.006
159	M	A	50-10-30	.015	-.017	-.001
40	M	D	30-50-10	-.028	.069	.014
47	M	D	10-50-30	.040	.015	.002
98	M	D	10-50-30	.027	.019	.023
119	M	D	30-50-10	.024	.054	.017
151	M	D	30-10-50	.055	-.001	.047
165	M	D	10-30-50	.008	.029	.045

APPENDIX A3

Raw Scores (in Inches) on the Visual Figural After-Effect Test at an Inter-Figural Distance of .063 Inch

Subject	Sex	Direction	Order	Inspection-Time		
				10	30	50
7	F	A	50-30-10	.001	.023	.031
37	F	A	50-10-30	.036	-.004	.023
56	F	A	10-30-50	.013	.012	-.001
75	F	A	10-50-30	-.001	-.023	-.003
92	F	A	10-50-30	-.028	-.006	-.030
148	F	A	30-10-50	.004	.001	.018
21	F	D	30-10-50	-.010	-.001	.080
70	F	D	30-50-10	.009	-.006	.011
79	F	D	50-10-30	-.042	.034	-.036
118	F	D	50-10-30	.007	.026	.016
126	F	D	30-10-50	.014	.005	.013
156	F	D	10-50-30	-.032	.029	.033
27	M	A	30-50-10	.033	.018	.016
60	M	A	30-10-50	.005	.008	.023
116	M	A	10-30-50	.010	.012	.037
121	M	A	50-30-10	-.001	-.016	.013
132	M	A	30-10-50	.020	.042	.026
144	M	A	50-10-30	.030	.004	.009
34	M	D	10-50-30	-.002	.038	.002
52	M	D	10-30-50	.002	.019	.015
54	M	D	50-30-10	.068	.020	.011
105	M	D	30-10-50	.025	.031	.058
137	M	D	50-30-10	.051	.018	.028
146	M	D	10-30-50	-.001	.015	.014

APPENDIX A4

Raw Scores (in Inches) on the Visual Figural After-Effect Test at an Inter-Figural Distance of.125 Inch

Subject	Sex	Direction	Order	Inspection-Time		
				10	30	50
16	F	A	30-10-50	-.004	.016	-.010
28	F	A	30-50-10	-.014	.021	-.002
69	F	A	50-30-10	-.010	-.013	-.050
104	F	A	30-50-10	.032	.020	.013
110	F	A	30-10-50	.027	.016	.038
138	F	A	50-30-10	.019	.018	-.018
5	F	D	10-50-30	.035	.047	.031
24	F	D	50-10-30	.006	.016	-.007
61	F	D	10-30-50	-.014	-.029	.001
109	F	D	10-30-50	.032	.013	.041
113	F	D	50-30-10	-.005	.028	-.001
164	F	D	30-50-10	.014	-.023	.059
25	M	A	10-30-50	.040	.027	.018
30	M	A	10-50-30	.028	.039	.039
68	M	A	50-10-30	.020	.010	.019
114	M	A	10-50-30	.004	-.017	-.001
162	M	A	10-30-50	.042	.032	.036
168	M	A	50-10-30	.003	.039	.035
26	M	D	50-30-10	.070	.071	.093
41	M	D	30-10-50	.033	.027	.062
71	M	D	30-50-10	.049	.048	.034
94	M	D	50-10-30	-.003	.057	-.022
128	M	D	10-50-30	-.023	.033	.021
161	M	D	30-10-50	-.029	-.022	.016

APPENDIX A5

Raw Scores (in Inches) on the Visual Figural After-Effect Test at an Inter-Figural Distance of .187 Inch

Subject	Sex	Direction	Order	Inspection-Time		
				10	30	50
35	F	A	50-10-30	.031	.022	.044
38	F	A	10-50-30	.003	.006	.010
90	F	A	50-30-10	.009	.035	.006
95	F	A	10-30-50	.019	-.004	-.004
152	F	A	30-10-50	-.030	-.016	-.020
163	F	A	30-50-10	.008	-.015	.021
10	F	D	30-50-10	-.024	.006	-.030
19	F	D	10-30-50	-.019	-.005	.021
36	F	D	30-10-50	.022	.015	.009
43	F	D	50-30-10	.007	.010	.023
91	F	D	30-50-10	.019	.032	.023
153	F	D	10-30-50	.045	.079	.049
15	M	A	50-30-10	-.013	.027	-.033
39	M	A	30-50-10	.017	.027	.027
64	M	A	10-30-50	.019	.007	.012
78	M	A	30-10-50	.012	.026	.015
115	M	A	50-10-30	.017	-.003	.046
136	M	A	10-50-30	-.007	-.012	-.012
77	M	D	50-10-30	-.055	.014	.010
80	M	D	10-50-30	.001	.026	.038
99	M	D	30-10-50	.011	.036	.018
125	M	D	10-50-30	.014	.031	.020
140	M	D	50-10-30	.021	.013	-.005
167	M	D	50-30-10	-.006	.016	.024

APPENDIX A6

Raw Scores (in Inches) on the Visual Figural After-Effect Test at an Inter-Figural Distance of .250 Inch

Subject	Sex	Direction	Order	Inspection-Time		
				10	30	50
4	F	A	30-10-50	.008	-.007	.008
23	F	A	10-30-50	-.008	-.007	-.005
42	F	A	50-10-30	-.043	.027	.011
97	F	A	50-10-30	-.008	.028	.019
117	F	A	10-30-50	.010	-.039	-.015
147	F	A	30-10-50	.003	.025	.025
1	F	D	50-10-30	-.079	-.072	-.094
53	F	D	30-10-50	-.013	.012	-.039
67	F	D	10-30-50	.031	.031	.037
88	F	D	30-10-50	.018	.021	.035
124	F	D	30-50-10	-.010	-.024	-.001
142	F	D	50-10-30	.004	.034	.004
31	M	A	30-50-10	.018	.017	-.009
57	M	A	10-50-30	.035	-.005	.016
86	M	A	10-50-30	-.003	-.019	.000
129	M	A	30-50-10	.003	.037	-.008
141	M	A	50-30-10	.045	.028	.018
8	M	D	10-50-30	-.012	-.041	-.034
29	M	D	50-30-10	.019	.000	.020
73	M	D	30-50-10	.030	-.007	.059
103	M	D	50-30-10	-.049	-.023	-.002
130	M	D	10-30-50	.022	.023	.033
149	M	D	10-50-30	.021	-.006	.020
72	M	A	50-30-10	-.020	-.011	.004

APPENDIX A7

Raw Scores (in Inches) on the Visual Figural After-Effect Test at an Inter-Figural Distance of .375 Inch

Subject	Sex	Direction	Order	Inspection-Time		
				10	30	50
12	F	A	10-30-50	-.028	.045	-.028
96	F	A	10-50-30	-.013	.026	-.036
101	F	A	30-50-10	.006	.002	.012
133	F	A	50-30-10	.010	.013	.015
160	F	A	30-10-50	.087	.068	.024
22	F	D	50-30-10	-.001	-.001	-.014
51	F	D	10-30-50	.029	.003	.050
66	F	D	50-30-10	-.015	.032	.060
83	F	D	30-50-10	-.014	-.055	.001
85	F	D	30-10-50	.038	.025	.057
120	F	D	10-30-50	-.005	.014	.055
17	M	A	30-10-50	.018	.022	.009
62	M	A	50-10-30	.016	.010	.005
84	M	A	10-50-30	.022	.028	-.004
127	M	A	50-30-10	-.026	.017	-.005
134	M	A	10-30-50	.023	.036	.015
155	M	A	50-10-30	.007	.010	.007
14	M	D	50-10-30	-.023	.008	-.005
48	M	D	10-50-30	.023	.019	.023
55	M	D	30-10-50	.010	.104	.034
100	M	D	50-10-30	.028	.034	.014
154	M	D	30-50-10	-.002	.001	.002
157	M	D	10-50-30	-.017	-.002	.021
46	F	A	30-50-10	.014	.014	.024

APPENDIX B1

Raw Scores (in Inches) on the Kinesthetic Figural After-Effect Test with an Inspection-Width of 2.0 Inches

Subject	Sex	Inspection-Time (Sec.)	Direction	
			Ascending	Descending
9	F	10	-.088	.160
23	F	10	.038	-.042
70	F	10	.036	-.134
83	F	10	.001	-.051
95	F	10	-.277	-.045
96	F	10	-.032	.047
1	F	50	.063	.213
37	F	50	-.139	-.008
53	F	50	-.100	.035
106	F	50	-.162	-.108
108	F	50	-.092	.081
153	F	50	.055	.038
15	M	10	.086	.154
44	M	10	.083	-.029
54	M	10	.065	.204
121	M	10	.000	.042
140	M	10	-.164	.014
145	M	10	.165	.052
13	M	50	-.018	.220
29	M	50	-.074	.095
62	M	50	-.007	.193
84	M	50	-.057	.039
155	M	50	-.060	.113
157	M	50	.027	-.013

APPENDIX B2

Raw Scores (in Inches) on the Kinesthetic Figural After-Effect Test with an Inspection-Width of 2.5 Inches

Subject	Sex	Inspection-Time (Sec.)	Direction	
			Ascending	Descending
19	F	10	.028	.065
21	F	10	-.118	.039
56	F	10	.180	.169
69	F	10	-.081	.125
113	F	10	.013	.059
122	F	10	.007	-.016
36	F	50	.195	.114
76	F	50	-.053	.066
82	F	50	-.036	.125
87	F	50	.154	.171
148	F	50	.078	-.025
152	F	50	.052	.161
31	M	10	-.003	.116
60	M	10	.055	.088
89	M	10	.015	.141
98	M	10	-.081	.100
141	M	10	.082	.034
144	M	10	-.059	.147
2	M	50	-.086	-.022
14	M	50	-.223	.066
30	M	50	-.067	.232
64	M	50	.003	.052
72	M	50	-.026	.183
150	M	50	-.007	.151

APPENDIX B3

Raw Scores (in Inches) on the Kinesthetic Figural After-Effect Test with an Inspection-Width of 3.0 Inches

Subject	Sex	Inspection-Time (Sec.)	Direction	
			Ascending	Descending
12	F	10	.102	.219
24	F	10	-.200	.019
58	F	10	-.291	-.076
79	F	10	.228	.260
109	F	10	.229	.214
123	F	10	.029	.203
7	F	50	-.131	.388
22	F	50	-.129	.268
75	F	50	.064	-.015
92	F	50	.019	.141
131	F	50	-.071	.056
133	F	50	-.111	-.001
26	M	10	.042	.248
55	M	10	-.003	.088
77	M	10	.009	.156
99	M	10	.008	.101
132	M	10	.081	.081
134	M	10	-.076	.094
17	M	50	.116	.164
41	M	50	.000	.149
63	M	50	.030	-.066
135	M	50	-.060	.314
146	M	50	.272	.223
158	M	50	.076	.094

APPENDIX B4

Raw Scores (in Inches) on the Kinesthetic Figural After-Effect Test with an Inspection-Width of 3.5 Inches

Subject	Sex	Inspection-Time (Sec.)	Direction	
			Ascending	Descending
42	F	10	.031	.248
49	F	10	.250	.316
67	F	10	-.059	.098
102	F	10	-.259	.046
104	F	10	.070	.350
120	F	10	.087	-.088
45	F	50	.074	.102
51	F	50	-.097	.146
61	F	50	.036	.253
97	F	50	.026	.109
111	F	50	.118	.085
117	F	50	.074	-.055
48	M	10	-.046	.035
57	M	10	.118	.050
94	M	10	.110	-.009
100	M	10	-.099	.040
125	M	10	.127	.132
128	M	10	.042	-.037
52	M	50	.208	.411
59	M	50	.052	.129
93	M	50	.150	.112
115	M	50	.083	-.035
116	M	50	.152	.237
127	M	50	.155	.184

APPENDIX B5

Raw Scores (in Inches) on the Kinesthetic Figural After-Effect Test with an Inspection-Width of 4.0 Inches

Subject	Sex	Inspection-Time (Sec.)	Direction	
			Ascending	Descending
16	F	10	.111	.292
38	F	10	.116	.149
43	F	10	.335	.003
90	F	10	-.035	.082
101	F	10	.087	.016
138	F	10	-.013	.101
3	F	50	.070	.214
11	F	50	.178	.181
32	F	50	.135	.013
66	F	50	.129	.140
112	F	50	.132	-.037
118	F	50	.052	.127
8	M	10	-.094	.157
27	M	10	.005	.156
39	M	10	-.043	-.115
40	M	10	-.048	.083
137	M	10	.119	.050
149	M	10	.074	.207
33	M	50	-.103	.114
50	M	50	.144	.219
68	M	50	.167	.228
114	M	50	-.153	.233
119	M	50	.088	.268
129	M	50	.170	.107

APPENDIX B6

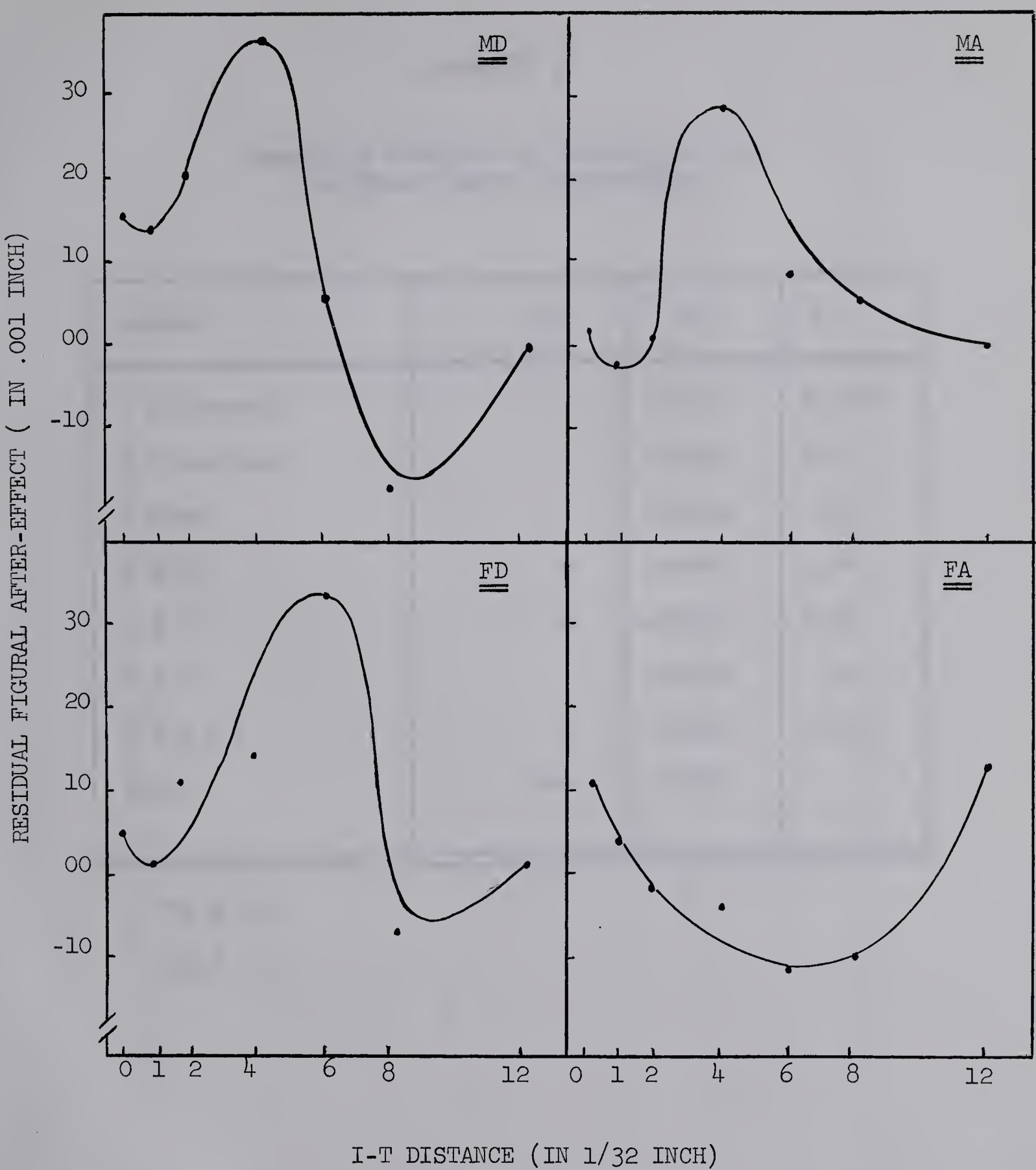
Raw Scores (in Inches) on the Kinesthetic Figural After-Effect Test with an Inspection-Width of 4.5 Inches

Subject	Sex	Inspection-Time (sec.)	Direction	
			Ascending	Descending
10	F	10	.108	.051
28	F	10	-.020	-.031
35	F	10	.041	.012
91	F	10	.031	-.045
142	F	10	.141	.203
143	F	10	-.084	.209
5	F	50	.150	.247
46	F	50	.125	.056
74	F	50	.004	-.111
88	F	50	.086	.258
126	F	50	.349	.242
147	F	50	.097	.292
6	M	10	.067	.044
71	M	10	.339	.115
73	M	10	-.130	.136
80	M	10	.044	.051
130	M	10	-.138	.005
136	M	10	.022	.158
20	M	50	-.004	.012
25	M	50	.191	.157
78	M	50	.137	.053
81	M	50	.007	.171
151	M	50	.071	.158
154	M	50	.269	.116

APPENDIX B7

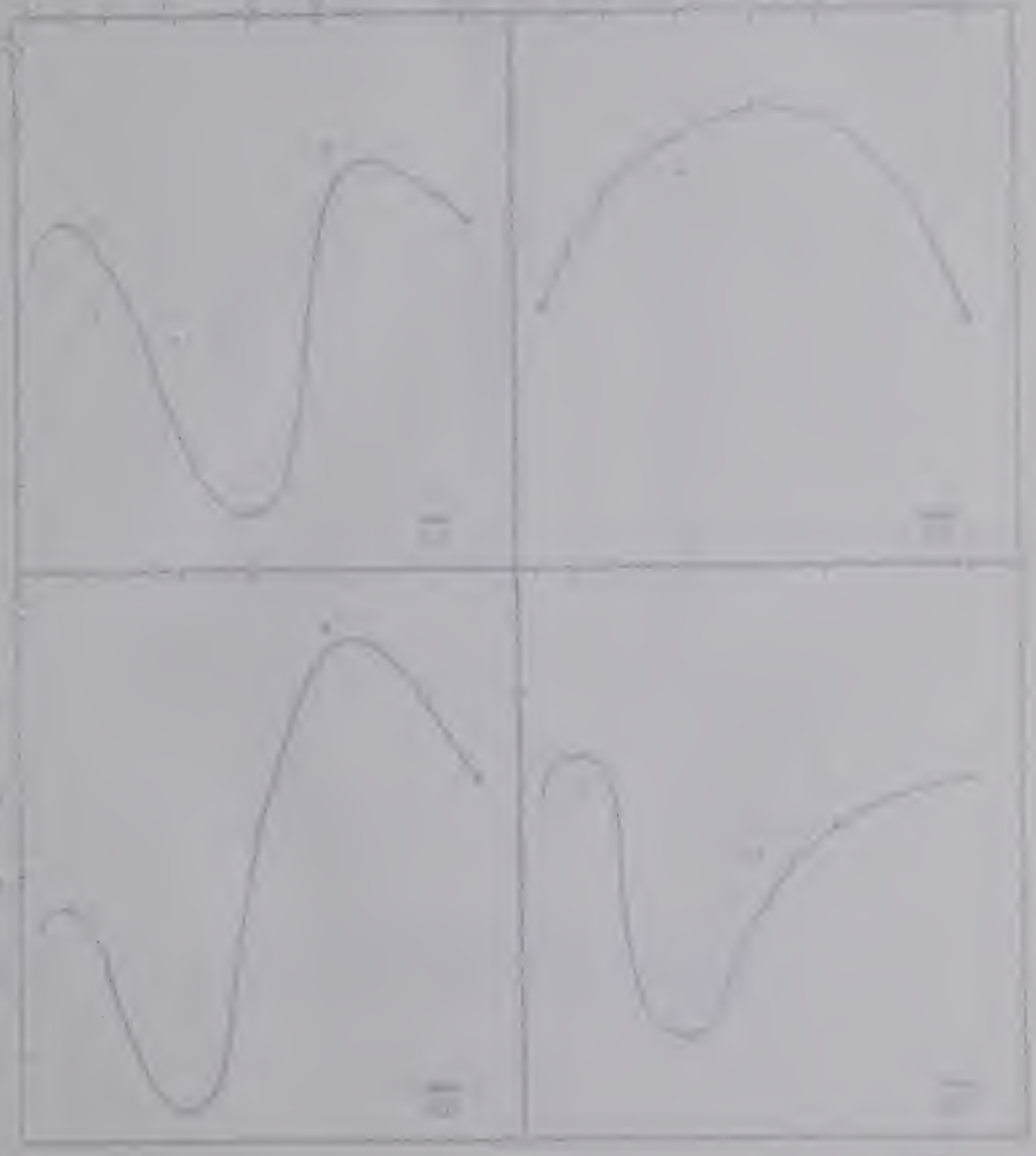
Raw Scores (in Inches) on the Kinesthetic Figural After-Effect Test from the Control Group

Subject	Sex	Direction	
		Ascending	Descending
4	F	-.072	.082
18	F	-.284	.122
65	F	.084	.093
85	F	-.320	.193
107	F	-.079	.091
110	F	-.056	.292
34	M	.032	.131
47	M	-.047	.190
86	M	-.034	.011
105	M	.067	.009
139	M	.057	-.015
161	M	-.010	-.035



APPENDIX C

Distance gradient of residual figural after-effect in male (M) and female (F) subjects as a function of ascending (A) and descending (D) alignments. This shows that the figural after-effect from the experimental trials did not dissipate after 150 seconds of rest. Curves are fitted by eye.



APPENDIX D

Summary of Analysis of Variance on the Residual Figural After-Effect

Source	df	MS	F
A (Distance)	6	.001447	2.98**
B (Direction)	1	.001685	3.47
C (Sex)	1	.000402	.83
A X B	6	.000807	1.66
A X C	6	.00803	1.65
B X C	1	.000059	.12
A X B X C	6	.001111	2.30*
Error	140	.00486	

*$p < .05$

**$p < .01$

APPENDIX E

Summary of Analysis of Variance on Visual Figural After-Effect Scores from Subjects who Showed Displacement in Predicted Direction

	Males			Females		
Source of Variation	df	MS	F	df	MS	F
A (Distance)	6	.000902	1.87	6	.000456	.91
Error	57	.000483		51	.000499	
B (Time)	2	.000067	.33	2	.001368	3.26*
A X B	12	.000281	1.37	12	.000054	.13
Error	129	.000204		102	.000419	

*$p < .05$

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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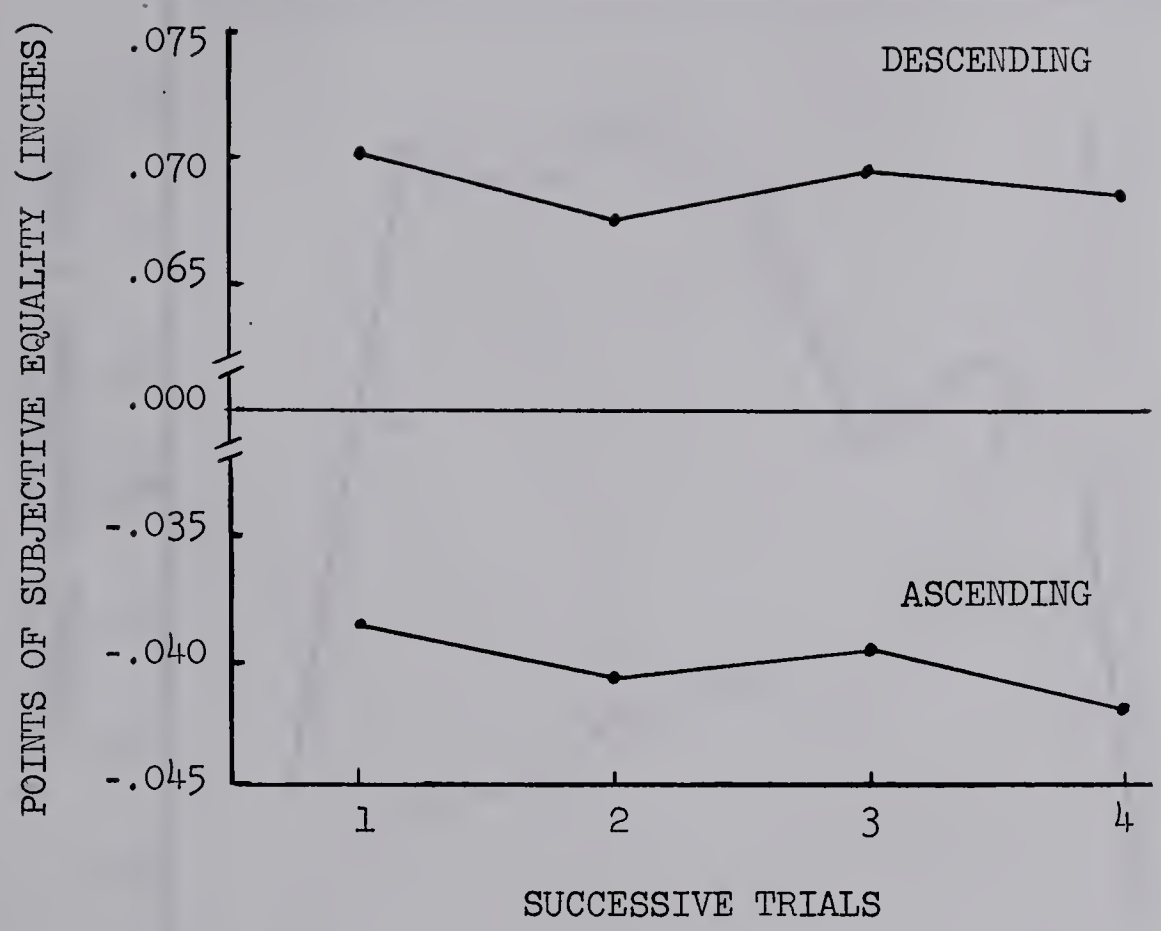
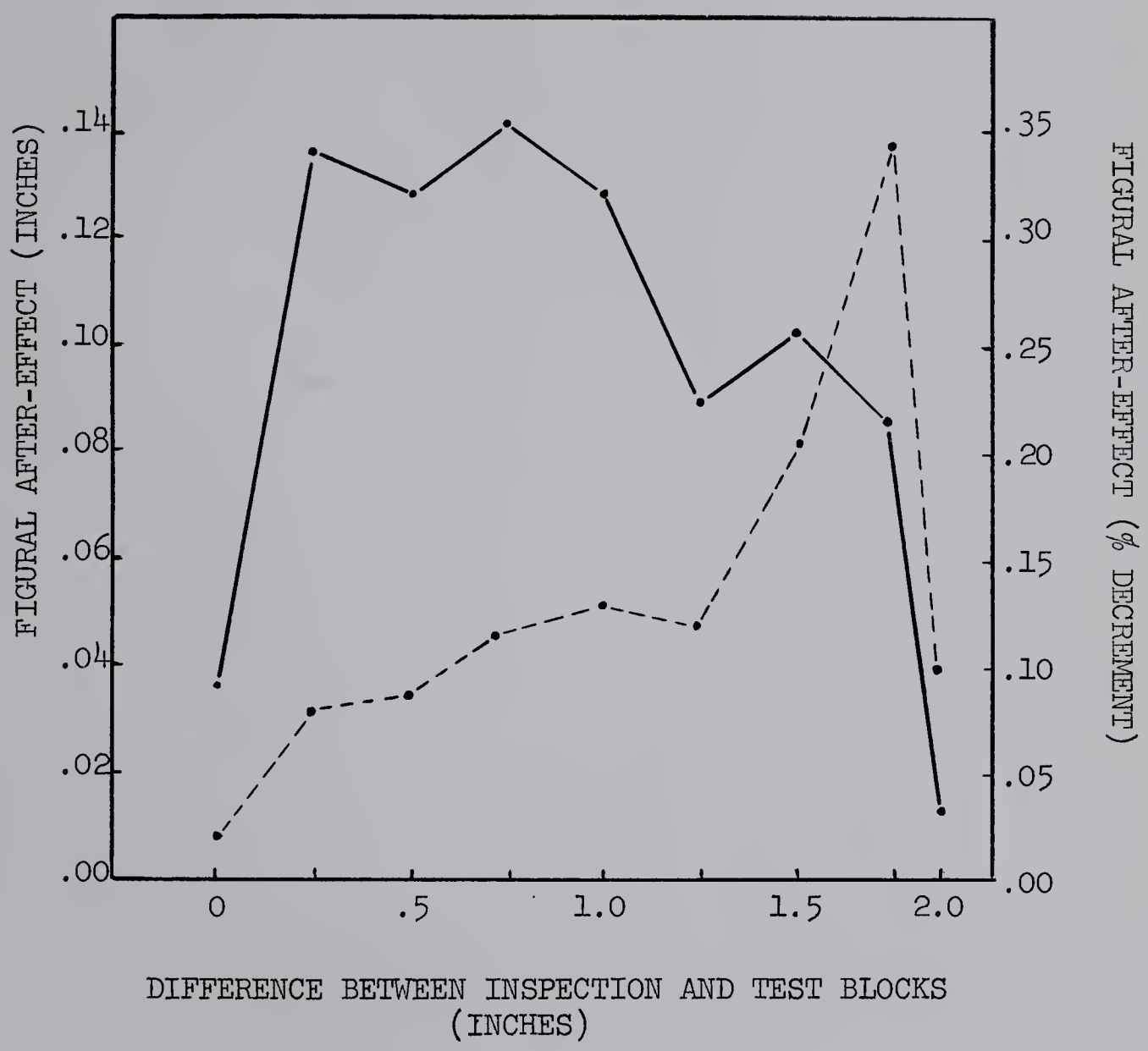


APPENDIX F

Points of Subjective Equality of Visual Position Judgments as a Function of Successive Trials.



APPENDIX G

Charles & Duncan's (1959) results on the distance gradient in kinesthetic figural after-effects. The solid line depicts results as originally presented by Charles & Duncan. The Broken line represents the same data in terms of percent decrement of the test-block.